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Science Focus

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The search begins at the heart of our Galaxy

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Thank you, Sylvia

Sylvia left a gift in her Will to help conquer Stroke

The first we knew of Sylvia was when we received notification of the gift she'd left us in her Will. Shortly after, a beautiful story of a much-loved woman began to unfurl.

Friends remembered Sylvia's kind-heart and her wish to help others. She spent part of her adult-life caring for her mother, and developed a passion for medicine. Becoming a medical secretary was her next step and, in the course of her career, she discovered the devastating impact a stroke could have on people and their families. She saw that research and treatment were vastly under-funded, and she decided to remember the Stroke Association in her Will.

Sylvia's gift has helped fund our work to conquer stroke. She's supported research to prevent and treat stroke, and she's helped care for survivors. And that's something you can do too – in the same way.

If you would like to learn more about remembering the Stroke Association in your Will, please get in touch.

Call 020 75661505 email legacy@stroke.org.uk
or visit stroke.org.uk/legacy

Stroke
association

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Why don't spiders stick to their own webs? → p88

FROM THE EDITOR

Last year, my resolution was to run a 5K. Not straight away, I might have died. But since people won't stop going on about how good running is, I figured I ought to try the Couch to 5K system that's supposed to help people like me pry themselves off the sofa. But by the time 1 January came around, I had caught a cold. Then when the office reopened, I was too busy. After that I was too tired, too cold and, let's be honest, too lazy.

When I set my resolution, I knew exactly how busy, cold and difficult it was going to be. The real problem was I lacked the willpower to see it through. Self-control, whether it's saying no to dessert or putting some money aside, has never been something I'm very good at. That's why I started looking into willpower: I wanted to know whether there was still hope, or whether I should just give up and settle into the Dan-shaped groove in the sofa.

Fortunately, I found some good news: I shouldn't give up on resolutions. Scientists are discovering all kinds of weird and wonderful ways people can improve their willpower. You just have to start by changing your frame of mind. Head to p54 to find out how researchers are rethinking the science of self-control…

Daniel Bennett

Daniel Bennett, Editor

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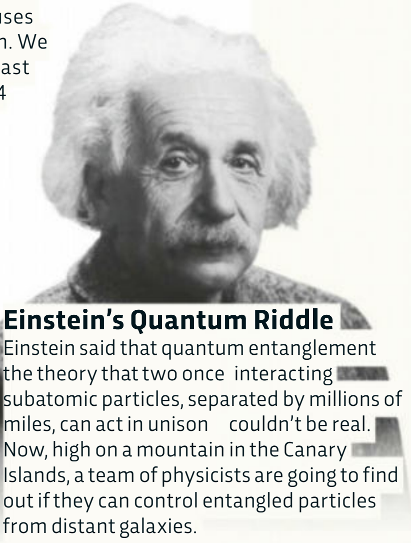
ON THE BBC THIS MONTH...

Addicted To Painkillers? Britain's Opioid Crisis

This *Horizon* special with our own columnist Dr Michael Mosley investigates the use of opioids both here and in America. He meets patients with chronic pain who are on the route to an addiction, and speaks to the GPs struggling to find ways to help them. Mid-January, BBC Two

Art Of Now: The Last Exposure

Garry Fabian Miller has spent 30 years creating camera-less photography – using photosensitive paper, long exposures and images funnelled into shapes made by the Sun. But the solution he uses to develop his prints is no longer in production. We join him as he sets foot in a darkroom for the last time. Tuesday 14 January, 11:30am, BBC Radio 4



Einstein's Quantum Riddle

Einstein said that quantum entanglement the theory that two once interacting subatomic particles, separated by millions of miles, can act in unison couldn't be real. Now, high on a mountain in the Canary Islands, a team of physicists are going to find out if they can control entangled particles from distant galaxies.
Mid January, BBC Four

COVER: MAGIC TORCH THIS PAGE: BBC, ALAMY, GETTY IMAGES

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HAYLEY BENNETT

The islands of Orkney produce more renewable energy than they can use. Science writer Hayley finds out the secret to their success. → p46

JV CHAMARY

JV is a science writer with a PhD in molecular evolution and genetics. This month, he gets hands-on with high street health test kits to find out if they're any good. → p68

SONIA CONTERA

Nature could hold the nanoscale solution to antibiotic resistance, the cure for cancer and more effective medicines. This issue, biological physicist Sonia tells us how she hopes to find blueprints to new nanotechnologies within our own bodies. → p64

STUART CLARK

It's only a matter of time before we start mining the Moon. Astronomy writer Stuart explores the consequences of a lunar gold rush. → p76

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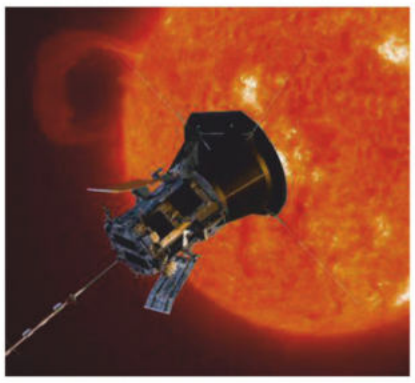

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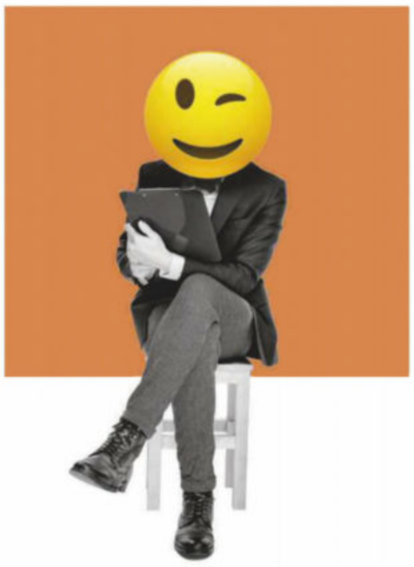

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The people of Orkney have become renewable energy pioneers. What can the rest of the world learn from their success?

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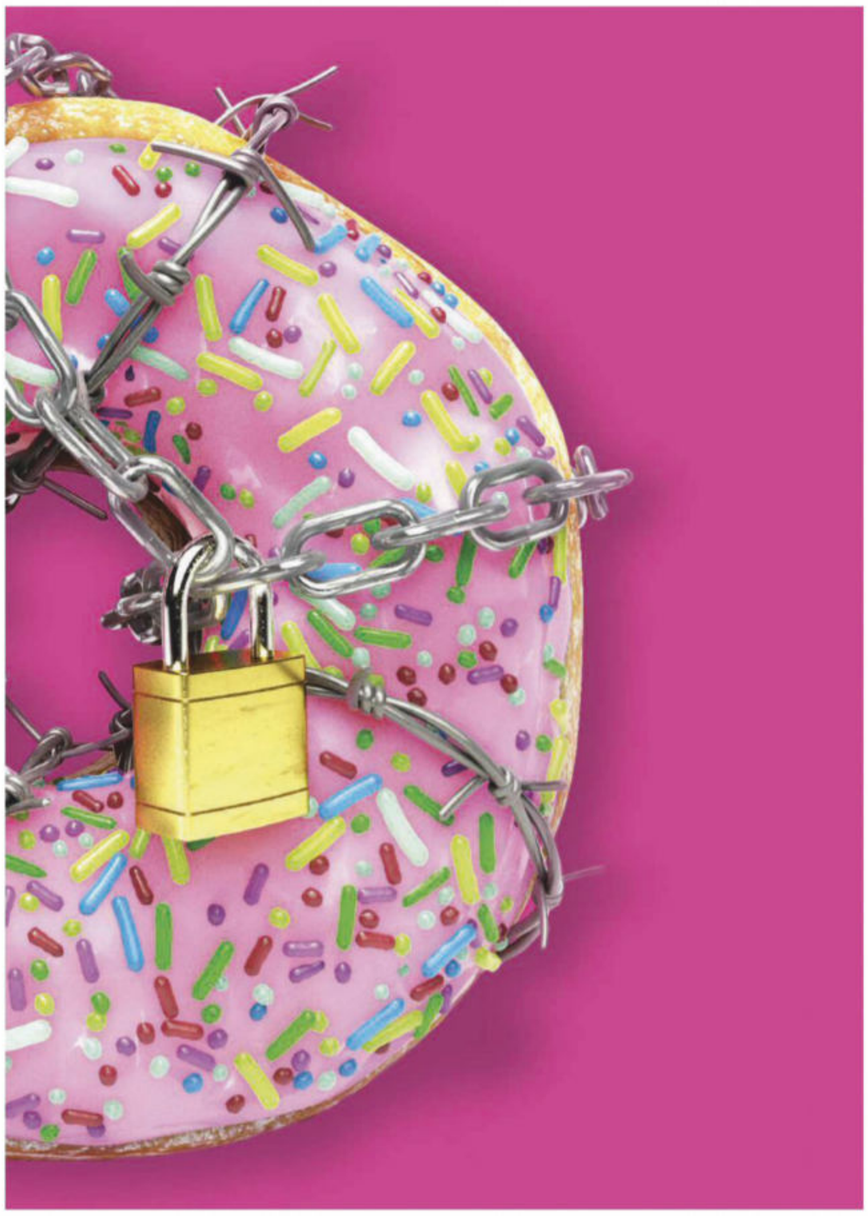

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> "ONE OF THE NICE THINGS ABOUT NANOTECH IS THAT IT CAN ACTUALLY MAKE TREATMENT CHEAPER. THAT'S SOMETHING MOST OF US THINK ABOUT WHEN WE DO OUR RESEARCH"

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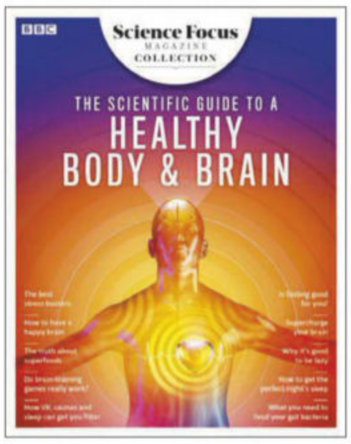
SPECIAL ISSUE



THE SCIENTIFIC GUIDE TO A HEALTHY BODY AND BRAIN
In this special edition, brought to you by the team at *BBC Science Focus*, discover what science says are the best ways to keep your brain sharp and your waistline slim, while staying fit, healthy and happy.
buysubscriptions.com/

EYE OPENER

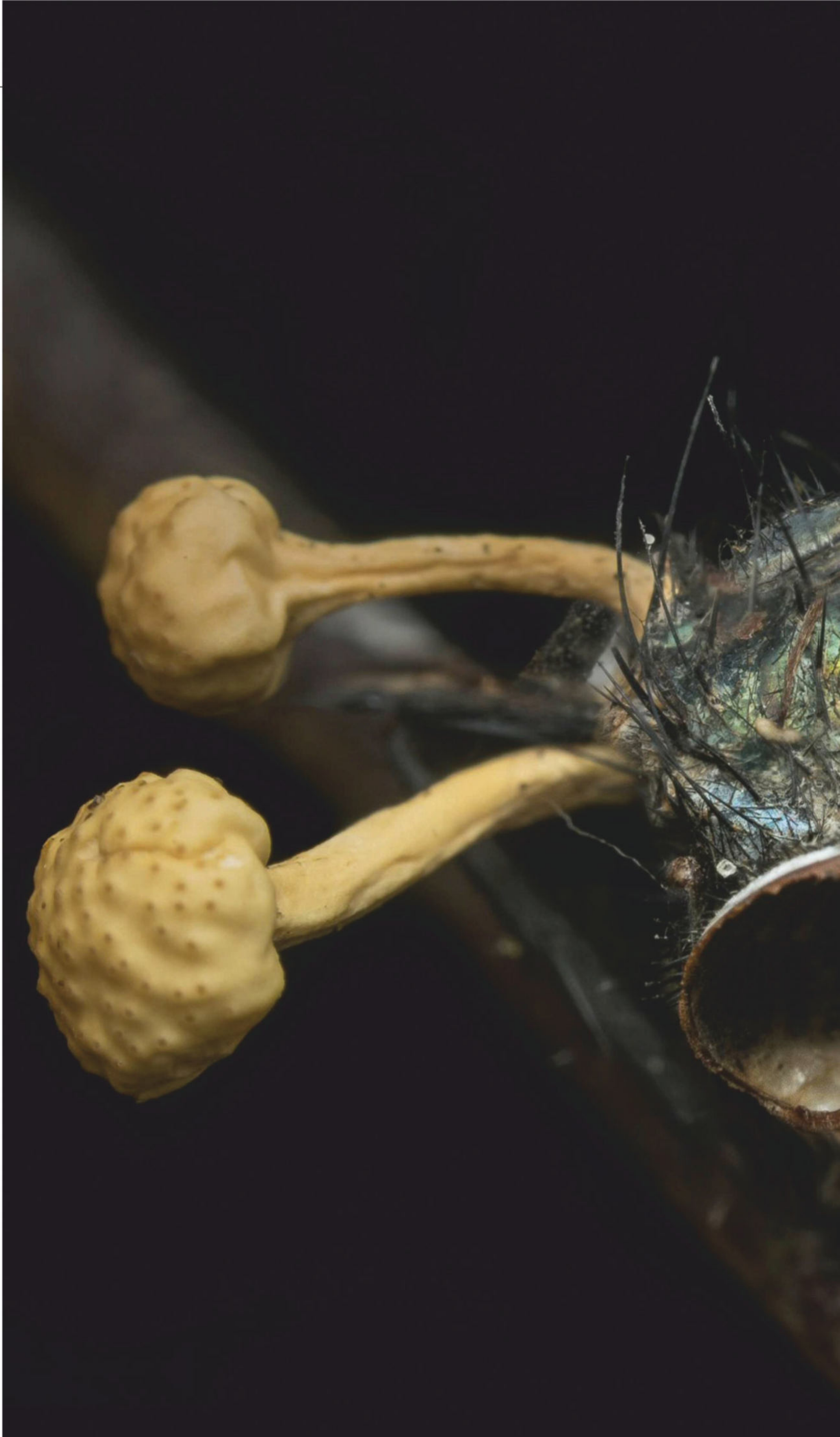
Fungal infection

SINGAPORE

This is the skull of a fly that was infected by the parasitic *Cordyceps* fungus. Comprising over 400 species, *Cordyceps* fungi grow inside the body of their host, eventually killing them, before erupting out of the corpse. The usual targets are insects and arachnids.

"*Cordyceps* is sometimes called the 'zombie fungus' because it can take over the host's nervous system," explains Dr Adam Hart, biologist and professor of science communication at the University of Gloucestershire.

The fungus overrides the host's behaviour, and induces it to climb a plant stem, with its abdomen facing upwards. "The insect eventually dies, thereby providing a great opportunity for the fungus to distribute its spores far and wide," says Hart. "The stalks you see coming out of the skull are the fruiting bodies of the fungus – much like a mushroom – that spread the fungal spores, going on to infect more insects."



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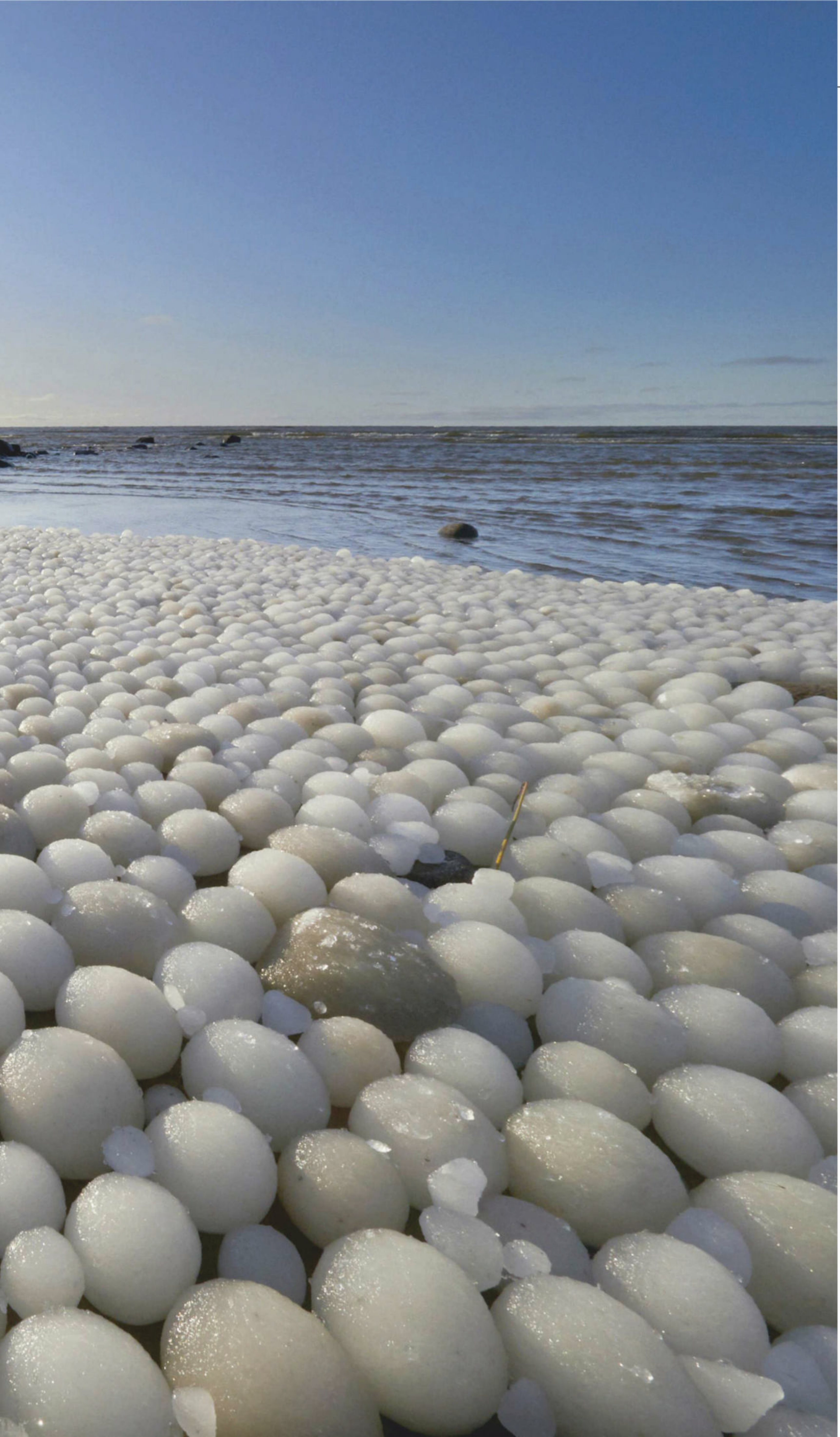

EYE OPENER

Beach balls

MARJANIEMI, FINLAND

When these 'ice eggs' fell from the sky onto the beach, they were much smaller. The perfect set of conditions – a little wind, and the right atmospheric and ocean temperatures – allowed them to grow to the dimensions seen here. The biggest was around the size of a football.

"The process of how these ice eggs formed is common in nature," says Dr Dann Mitchell, associate professor in atmospheric science at the University of Bristol. "It's the same as how hail forms. You have something called 'cloud condensation nuclei' in the atmosphere, which is basically just tiny particles of air pollution. Moisture condenses on those particles, and when they get too heavy, they fall as hail."

On the beach, these structures combine together and grow in size as the wind brings water from the ocean across them, which then freezes. "The gentle rocking of the ocean can smooth them over," explains Mitchell, thus forming their shape.

RISTO MATTILLA

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CONVERSATION

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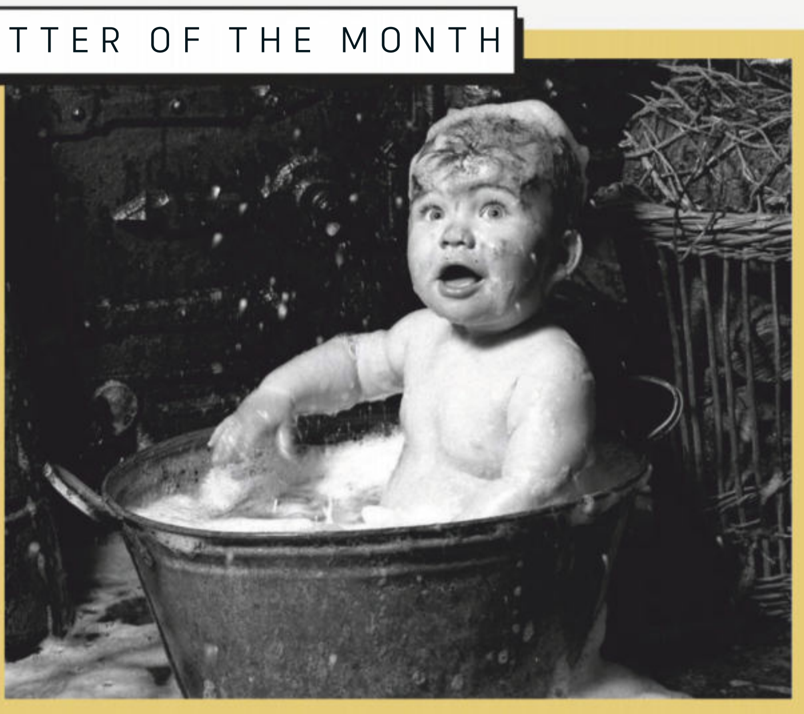
LETTER OF THE MONTH



Cleaning for cleaning's sake

In October, you asked if there was such a thing as being too clean (p34) and if readers would give up washing. These were the wrong questions to ask. You should have asked, "How clean is clean enough?" and "Have you thought about the impact of your daily shower on the environment?"

I am 79 years old. For more than half my life I lived without a shower. As a child, bath night was once a week. During the war, and post-war austerity, we had a bath with water no more than five inches deep. We weren't dirty.

I think everyone should adopt the minimum wash regime. It is not just the power used to heat the water that is damaging. The provision of clean water, and the treatment of waste water, consumes energy and uses many chemicals, so the less you use the better.

Maureen Armstrong, Bristol, *via email*

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins an Alcatel 3 2019 smartphone. The stylish SIM-free smartphone boasts a two-tone ombre design, and offers a 5.9-inch HD+ display, a 13MP main camera, and comes with 32GB internal storage.
alcatelmobile.com

WORTH £139.99

What's in a game?

In response to 'Heading and dementia: are footballers putting themselves at risk?' (December, p34), I wanted to point out that in my school there was no question of consent: sports were compulsory, any threat of injury being 'all part of the game'. I may be doing them an injustice, but I can imagine my sports teachers, and many others, being prepared to tolerate the occasional case of brain damage among their students for the sake of the game.

I do not believe that this is a desirable attitude, either for the students or more generally – this country benefiting far more from another Stephen Hawking than from another Paul Gascoigne, even if some people might consider it blasphemy to say so.

Peter Davey, Bournemouth, *via email*

All in the language

Be careful of your choice of words when writing about evolution (December, p15). The extra digit of the aye-aye did not evolve *to* help in climbing. That implies design or foreknowledge! It evolved *because* it helps climbing.

John Gribbin, *via email*

Not convinced...

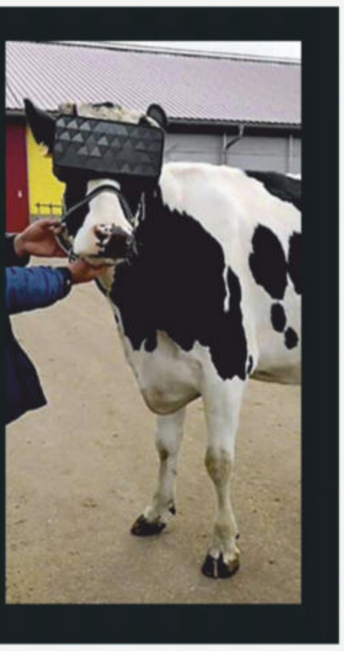
My initial thoughts after reading about the new Toyota hydrogen-powered car (December, p43) are that if it is going to cost as much as you say to fill the tank then it's a non-starter. Even more so as it will be marketed as a desirable car, at no doubt an unbelievable price to many.

As both electric and hydrogen cars have fewer complicated moving parts, the manufacturers (and governments) must eventually come to sense and realise that cost is important. If they could market these new vehicles at less cost than existing petrol cars then, and only then, will the mass general public want to swing over to buying them.

Clive Lewis, *via email*

Over on *Science Focus* Twitter...

Giving VR headsets to cows can boost the overall emotional mood of the herd, according to a rather unusual study last month. Photographic evidence led to us asking our Twitter followers the question: "What moo-vie do you think this cow is watching?"



Here are some of our favourite responses:

@Mantis_Shrimp **The Cud, The Bad And The Udderly**
@MarkLittlewood **Fiddler On The Hoof**
@DJMusgrove **Bridget Jones's Dairy**
@cottonscience **A Ruminant With A View**

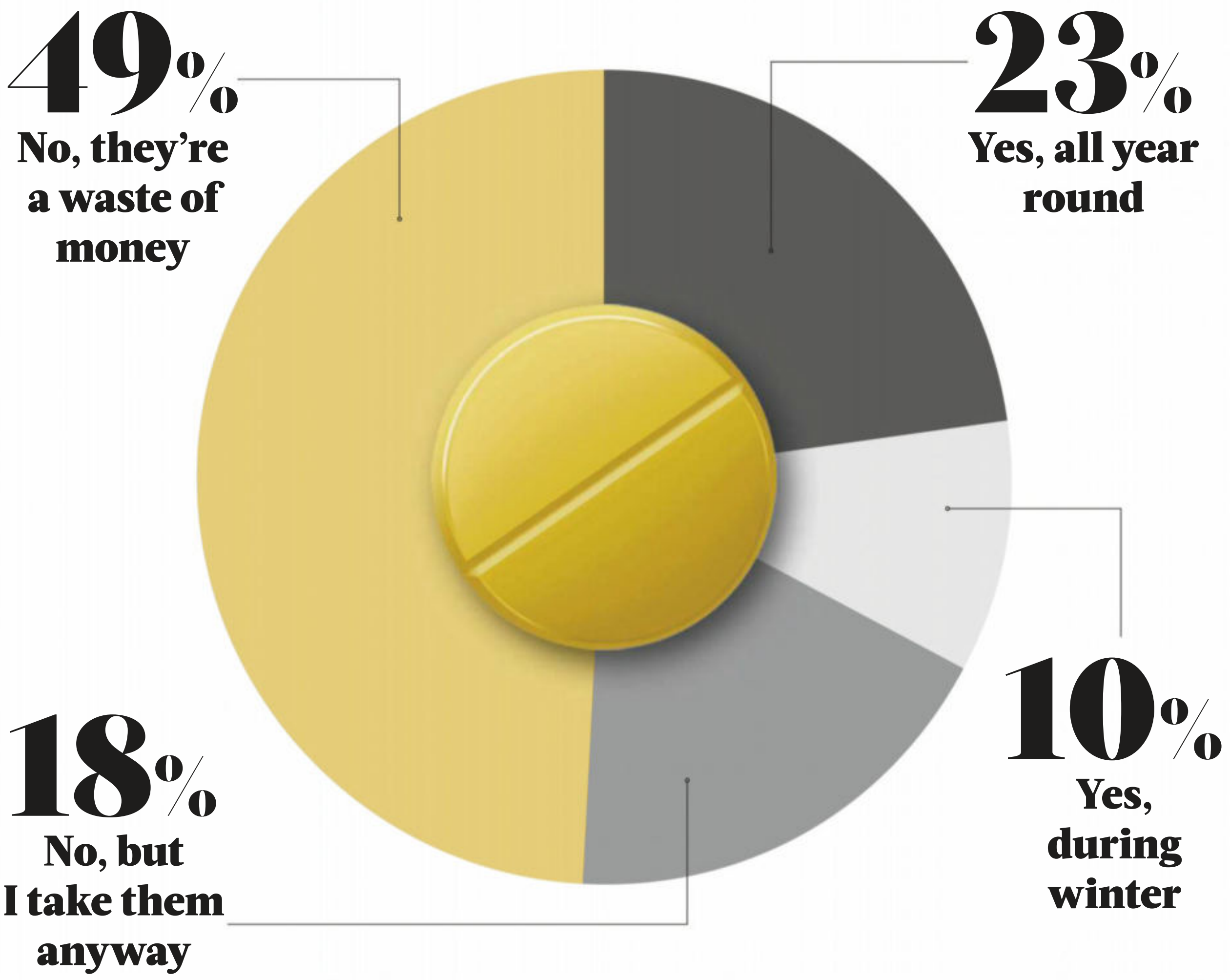
> *"DNA IS A WONDERFUL, COMPLICATED MACHINE THAT LINKS PHYSICS AND THE HISTORY OF LIFE ON EARTH TO THE ENVIRONMENT"*
>
> PROF SONIA CONTERA, p64

READERS' BUZZ

Your views on the burning science topics of the month

Many of us take supplements, particularly in winter, as we believe they'll help boost health and wellbeing, and stave off colds. But do they work? We looked at the research in last month's *Reality Check*, then asked our Twitter followers…

DO YOU THINK TAKING VITAMINS MAKES YOU FEEL BETTER?



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URGENT APPEAL: help Syrian refugee parents like Khitam to protect their children through the winter.

UNHCR
The UN Refugee Agency

Khitam lives with her four young children, husband Abdelsalam, and his elderly parents in a single, damp room of a half-built apartment block near Tripoli, Lebanon.

There are holes in the walls and ceiling, and they share a toilet with other refugee families crammed into the building. Khitam and Abdelsalam are mentally and physically exhausted after years of struggling to survive, unable to earn a living and fighting a daily, relentless battle to feed their children.

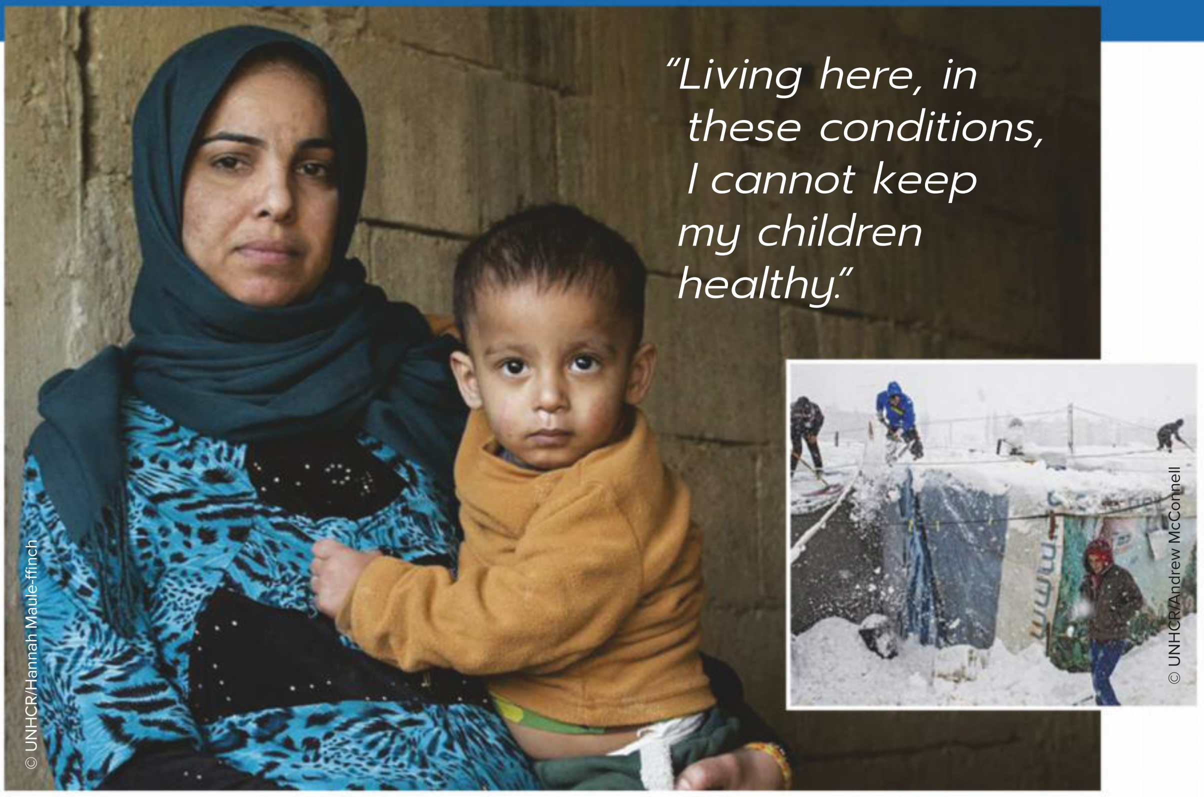
Right now, they are terrified by the prospect of another winter in their cold, uninsulated single room. Another winter where they will feel every blast of icy wind. Another winter where every time their children cough or sneeze they will fear they have contracted a lethal respiratory condition like pneumonia or tuberculosis.

100kph
WIND SPEEDS RECORDED DURING STORM NORMA IN LEBANON, JANUARY 2019

UNHCR, the UN Refugee Agency, needs your support to help parents protect their children this winter.

Please will you give £75 to provide a refugee family like Khitam's with a winter survival kit to protect against the freezing weather?

The kit contains essentials such as a heating stove, thermal blankets and a tarpaulin for insulation. It could mean survival for a family like Khitam's.


© UNHCR/Hannah Maule-ffinch
© UNHCR/Andrew McConnell

> *"Living here, in these conditions, I cannot keep my children healthy."*

Two winters ago, as a result of their exposed and unsanitary living conditions, Khitam and all four of her children became ill. Baby Bilal had a high temperature and diarrhoea. Her sons Khaled (3, pictured) and Abdul Rahman (8) had chest infections and their sister Fatimah (4) contracted worms. Khitam herself developed painful growths on her throat and lost her voice. Without access to a free healthcare system like we have in the UK, Khitam became overwhelmed with worry about how to pay for the treatment and medicines her children needed.

"I felt helpless. My children were coughing and crying and there was nothing I could do."

£75
could provide a Syrian refugee family with a winter survival kit

Khitam believes that without assistance from UNHCR "my children would be dead".

Across Lebanon and Jordan, seven of the last eight winters have brought heavy snowfall and temperatures regularly drop below 0°C.

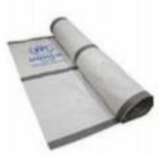
1.7 million Syrian refugees are living, like Khitam's family, in unfinished or derelict buildings, or in makeshift shelters, sometimes made of little more than wood and plastic sheeting. This coming winter, when temperatures are likely to fall below zero, the lives of the most vulnerable: young children, pregnant women and the elderly, are at grave risk from hypothermia, frostbite and diseases like pneumonia.

With a gift of £75 you can provide a winter survival kit containing a stove, blankets, winter clothes and a tarpaulin to help a family insulate and heat their home. Please give today – you could save the lives of children like Khitam's.

Give at **unhcr.org/wintersupport**
or call **0800 029 3883**

With £75, you can give a winter survival kit containing:

STOVE
For heating and cooking. An absolute essential.


TARPAULIN
For insulation. Keeps the cold out and the warmth in.

BLANKET
Families left their homes with nothing. A simple blanket could save a life.

WINTER CLOTHES
Hats, gloves, scarves and coats to keep families warm, both inside and outside of shelters.

Yes, I will help Syrian refugee families survive the winter

UNHCR
The UN Refugee Agency

Please accept my gift of: ☐ £75 ☐ £150 ☐ £225 My own choice of £

Please post urgently to: **Freepost UNHCR**. You do not need a stamp.

BFPAWI19A

Please debit my: ☐ Visa ☐ MasterCard ☐ Maestro

Card no. Maestro only

Valid from Expiry date Issue no. Maestro only

Signature Date / /

☐ I enclose a cheque or postal order made payable to UNHCR (Currently CAF cheques cannot be accepted)

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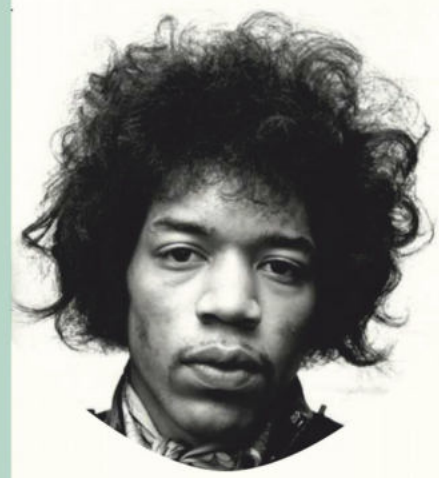

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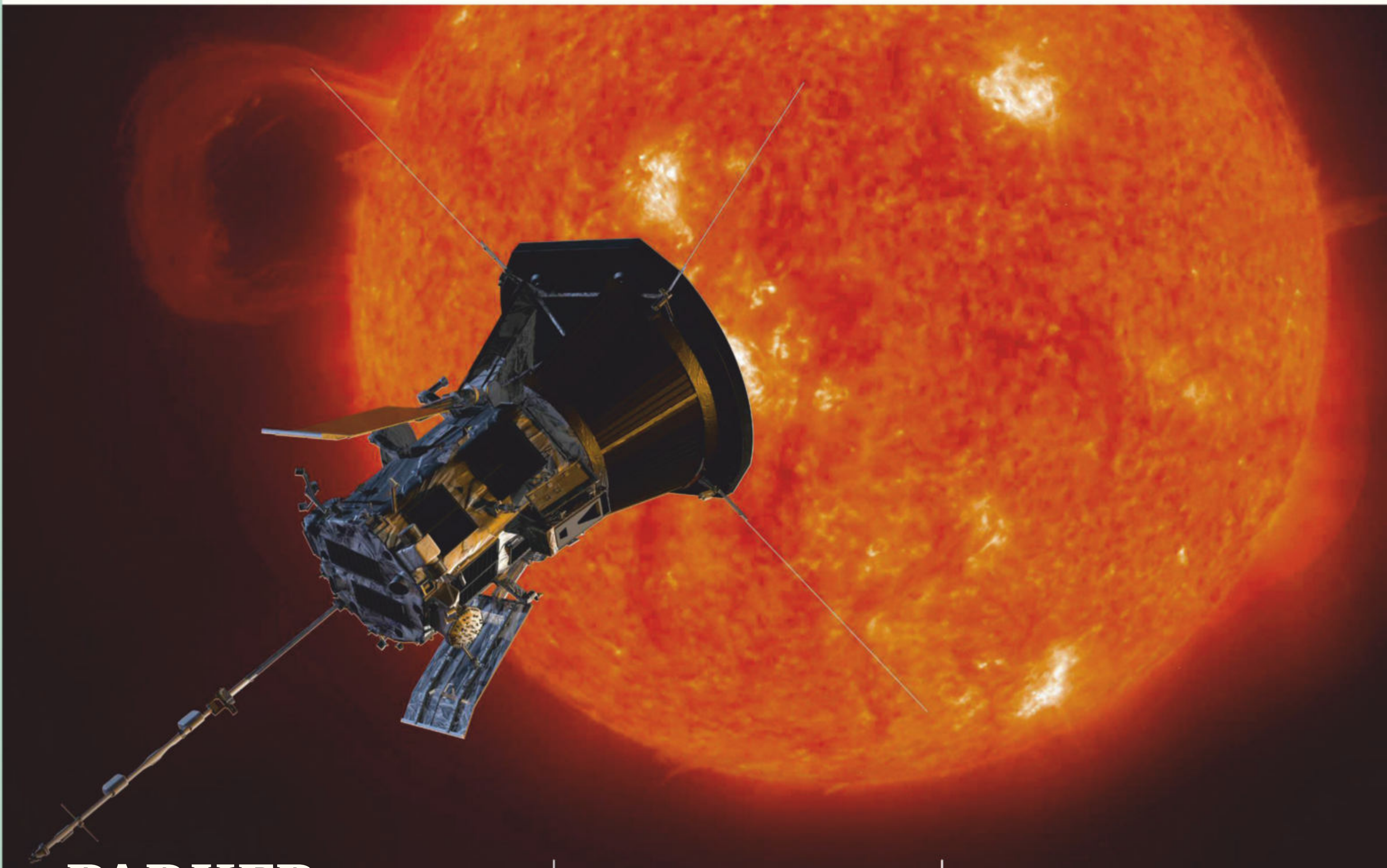


GETTY IMAGES, NASA

PARKER SOLAR PROBE SENDS BACK DATA FROM SUN'S SURFACE

Spacecraft on mission to 'touch the Sun' sends back first observations of the star's magnetic field, the dust-free zone that surrounds it, and the origin of the solar wind

In August 2018, NASA's Parker Solar Probe was successfully launched into space, quickly breaking the record for the closest-ever spacecraft to the Sun. Now, after completing just three of 24 planned passes through never-before-explored parts of the Sun's atmosphere, it is already delivering the goods. A clutch of new studies published in the journal *Nature* has unveiled tantalising new clues about the turbulent ebbing and flowing of the Sun's magnetic field, the movements of the solar wind, and the bizarre dust-free zone that envelops our star.

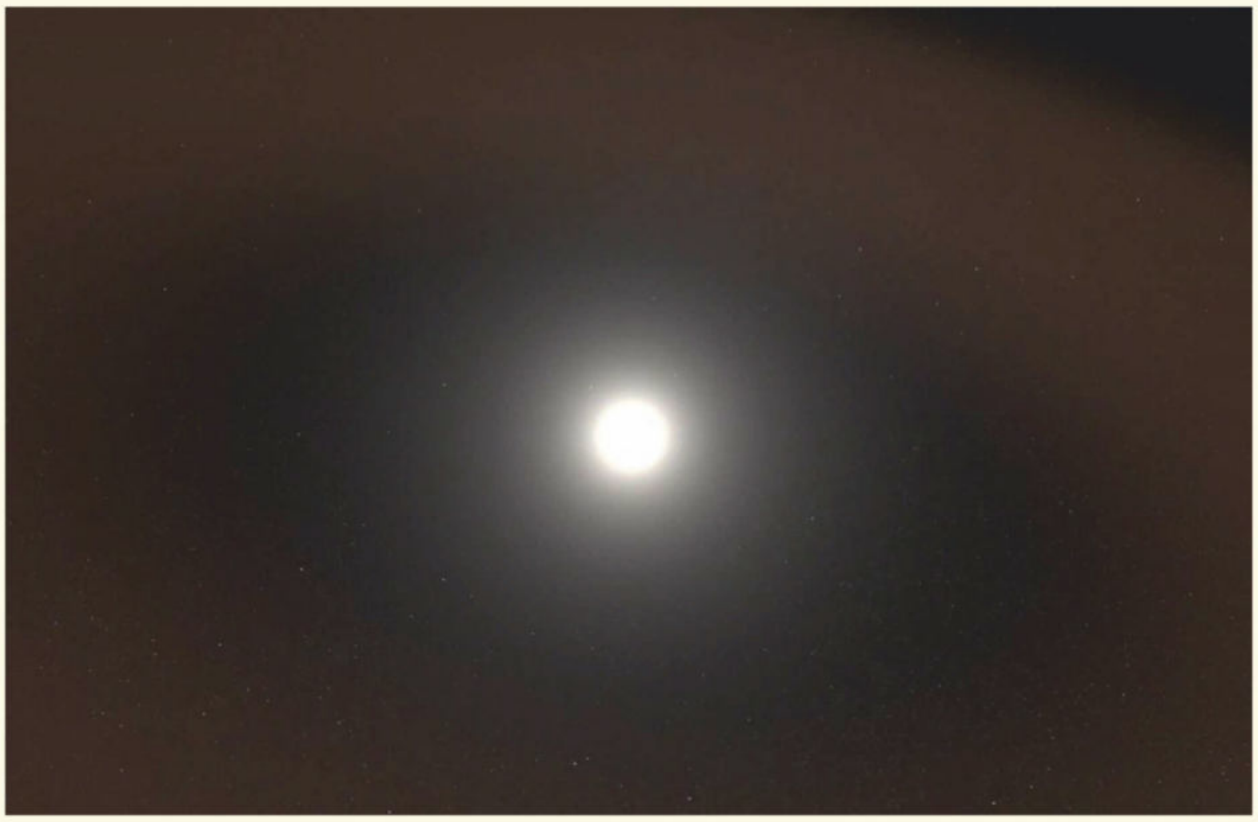
"This first data from Parker reveals our star, the Sun, in new and surprising ways," said Dr Thomas Zurbuchen, associate administrator for science at NASA headquarters in Washington. "Observing the Sun up close rather than from a much greater distance is giving us an unprecedented view into important solar phenomena and how they affect us on Earth, and gives us new insights relevant to the understanding of active stars across galaxies. It's just the beginning of an incredibly exciting time for heliophysics with Parker at the vanguard of new discoveries." ➲

White Island volcano Special report by Bill McGuire p22 **Tree of life** New species discovered in 2019 by the California Academy of Sciences p24 **Wormhole hunt** Scientists think there might be one at the centre of the Milky Way p26

News in brief

YOUTHFUL PERIODS OF STRESS COULD LEAD TO LATER SUCCESS

Feeling stressed? Don't worry, a little bit of stress at a young age could have a protective effect, according to researchers at the University of Michigan. While studying *Caenorhabditis elegans* roundworms, the team discovered that juvenile worms that produced more oxidants and free radicals – substances associated with stress and ageing – ended up living longer than worms that produced less. The researchers also found that exposing the young worms to external oxidants during development led to longer lifespans. "Experiencing stress at this early point in life may make you better able to fight stress you might encounter later in life," said Dr Daphne Bazopoulou, who led the research.



Cosmic dust is oddly absent from around the Sun

▶ Most of the material that escapes the Sun makes up the solar wind – a continual outflow of solar material that flows across the entire Solar System. This ionised gas, or plasma, carries with it the Sun's magnetic field, which stretches out in a giant bubble that spans more than 16 billion kilometres (10 billion miles). By the time it reaches Earth, a journey of more than 149 million kilometres (93 million miles), the solar wind is relatively uniform. Close up it's a different story entirely.

"The complexity was mind-blowing when we first started looking at the data," said Prof Stuart Bale, who leads Parker Solar Probe's FIELDS instrument suite, which studies the scale and shape of electric and magnetic fields. "Now, I've gotten used to it. But when I show colleagues for the first time, they're just blown away."

The team found that the magnetic field frequently makes rapid changes in direction, dubbed 'switchbacks', in which the field whips directly back on itself, though the exact source of this movement isn't yet understood.

The probe is also investigating the way in which the solar wind flows out from the Sun. Near Earth, we see the solar wind flowing almost radially – it streams directly from the Sun, straight out in all directions. But the Sun rotates as it releases the solar wind, so before it breaks free, the solar wind spins along with it. Now, for the first time, Parker has been able to observe the solar wind close enough to actually see it spinning.

"The large rotational flow of the solar wind seen during the first encounters has been a real surprise," said Dr Justin Kasper, who is principal investigator on Parker's SWEAP instrument, which takes measurements of the solar wind. "The high speeds we are seeing in these first encounters is nearly 10 times larger than predicted by the standard models."

Locating the exact point that the solar wind transitions from rotating along with the Sun to flowing directly outwards could lead to new insights into everything from the life cycles of stars to the early formation of planets.

> **"Getting data at the source is already revolutionising our understanding of our own star and stars across the Universe"**

Another discovery concerns the unusual dust-free zone that surrounds the Sun. Our Solar System is awash with dust – the cosmic crumbs of collisions that formed planets, asteroids, and comets billions of years ago. It was previously postulated that the scorching temperatures around the Sun would turn this dust to gas but the phenomenon was never directly observed.

"This dust-free zone was predicted decades ago, but has never been seen before," said Dr Russell Howard, principal investigator for the WISPR suite, the probe's imaging instrument. "We are now seeing what's happening to the dust near the Sun."

As the probe continues its journey, it will get ever closer to the Sun, culminating in three orbits around six million kilometres from the solar surface.

"The Sun is the only star we can examine this closely," said Nicola Fox, director of the Heliophysics Division at NASA. "Getting data at the source is already revolutionising our understanding of our own star and stars across the Universe. Our little spacecraft is soldiering through brutal conditions to send home startling and exciting revelations."

NASA, ALAMY, GETTY IMAGES X2 ILLUSTRATION: CHIARA BRAZZALE

They did what?

Screams analysed

WHAT DID THEY DO?

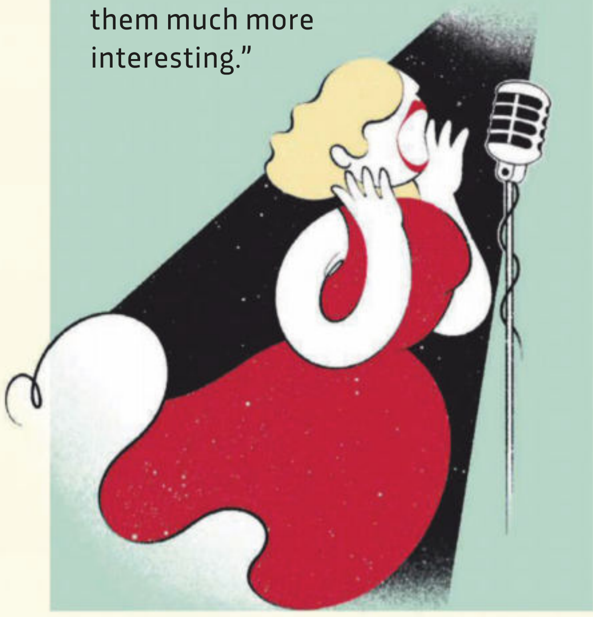
A team at Emory University in Atlanta, Georgia, played 182 participants a variety of high-intensity, visceral sounds – everything from shrieks recorded from TV and movie performances to the screams of non-actors reacting to events posted to sites such as YouTube. Among the sounds were screams of aggression, exclamation, excitement, fear or pain. Other calls included cries, laughter and yells. The participants had to say which sounds they classified as screams.

WHAT DID THEY FIND?

There were distinct acoustic attributes of the calls the participants classed as screams, included a higher pitch and roughness to the sound; a wider variability in frequency; and a higher peak frequency.

WHY DID THEY DO THAT?

Senior author Prof Harold Gouzoules began researching monkey screams in 1980, before becoming one of the few scientists studying human screams. He is interested in the role screams played in our development. "Animal screams occur almost always in the context of a fight or in response to a predator," he said. "Human screams happen in a much broader array of contexts, which makes them much more interesting."

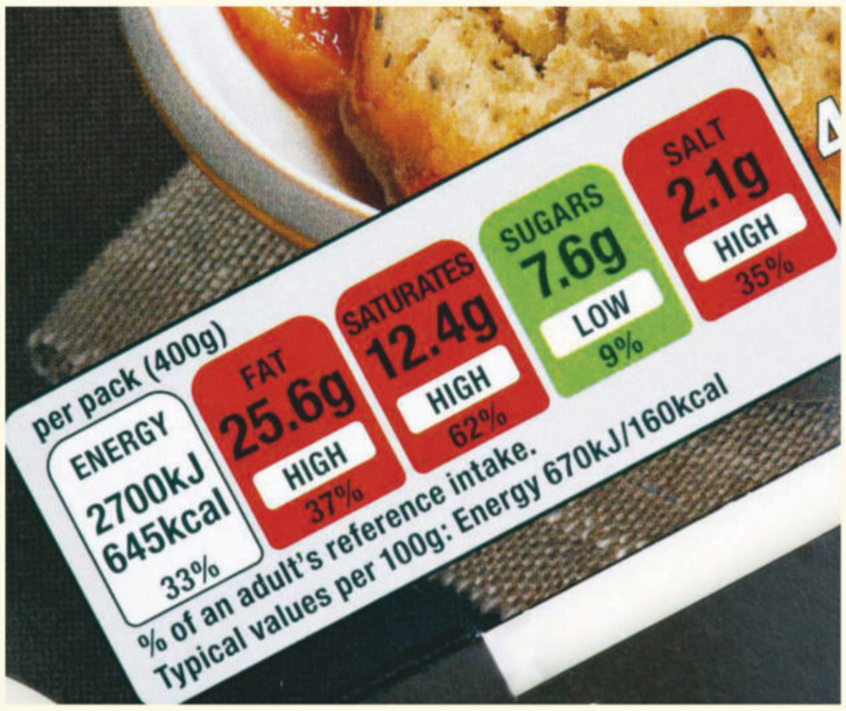


AIR POLLUTION MAY INCREASE THE RISK OF STROKE

A team from Taiwan's China Medical University compared health data from nearly 23 million people spanning from 2000 to 2013 with air pollution data over the same period. They found that high levels of two types of pollutants, total hydrocarbons (THC) and nonmethane hydrocarbons (NMHC), produced by transportation, coal power plants, and other gaseous emissions could increase the risk of ischemic stroke – when an artery to the brain is blocked – by a factor of three.

HEALTH

I should walk 500 miles (to burn off this Christmas dinner)



Confused by food nutrition labels? You're not alone. Now, researchers have suggested an alternative: labelling the amount and type of exercise needed to burn off the calories.

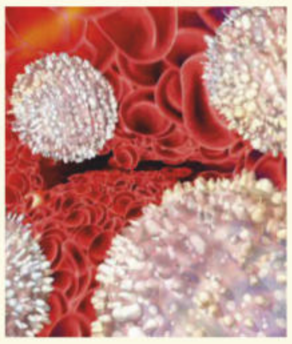
Current food and drink labels display nutritional information such as the amount of calories and fat. However, researchers led by Prof Amanda Daley at Loughborough University say that these labels are having a limited effect on changing buying habits. Instead, they propose a labelling system called 'physical activity calorie equivalent or expenditure' (PACE), which shows how many minutes or miles of physical activity are needed to burn off the calories. For example, a small bar of milk chocolate contains 230 calories, which would take about 42 minutes of walking, or 22 minutes of running, to burn off.

They pooled the data from 14 previous studies which compared the impact of PACE labelling with that of other types of food labelling, or with no food labelling at all. They calculated that PACE labelling could cut a person's daily calorie intake by up to 200 calories. "Public health agencies may want to consider the possibility of including policies to promote PACE food labelling as a strategy that contributes to the prevention and treatment of obesity and related diseases," said the researchers.

The UK's Royal Society for Public Health has already called for PACE labelling to replace the current system. However, not everyone is convinced. A spokesperson for the eating disorder charity Beat said: "We believe that anti-obesity campaigns that focus on weight instead of health are ineffective and that recommending more exercise is a futile and over-simplistic approach to a complex problem. Most urgently, public health campaigns must consider people's mental as well as their physical health, moving from obesity-shaming to evidence-based campaigns that instil confidence and support healthy eating."

YOUR BLOOD CAN SHOW YOUR AGE

The levels of certain proteins in your blood can reliably predict your age, scientists have found. Using blood samples from more than 4,000 people, aged 18 to 95, researchers at Stanford University School of Medicine were able to identify 373 different proteins that peak and trough across your lifespan. The blood test developed can also show if your physiological age is higher or lower than your real age, which may in the future be used to indicate those more at risk to age-related illnesses or to reveal the ageing effect of drugs and treatments.



Trending

YOUR GUIDE TO WHO'S SAYING WHAT ABOUT THE HOTTEST TOPICS IN THE WORLD RIGHT NOW

#JimiHendrix

Researchers at the Queen Mary University of London have debunked the urban myth that green parakeets were introduced to London in the 1960s by Jimi Hendrix. An extensive search of newspaper archives points to a series of intentional releases between 1929-1931, and in 1952 by media coverage of fatal 'parrot fever' outbreaks.

Adam London Tours

@AdamLondonTours

I get asked about this one all the time on my London Music Tours. Did #JimiHendrix introduce the parakeet to the UK? Like many of the best stories... it's NOT TRUE! Parakeets have been here since the 1860s. But the story doesn't want to go away.

Chislehurst's Best

@ChisAction

Frankly, we don't care whether Jimi Hendrix actually released parakeets... we just think it's the coolest idea! But here's a thing: we've rather come to like those green squawky things here in #Chislehurst ... how about you?

#AnxietyFeelsLike

A hashtag started by Twitter support community Mental Health Notes provided a platform for people to share their experiences of depression and anxiety.

ClairePA

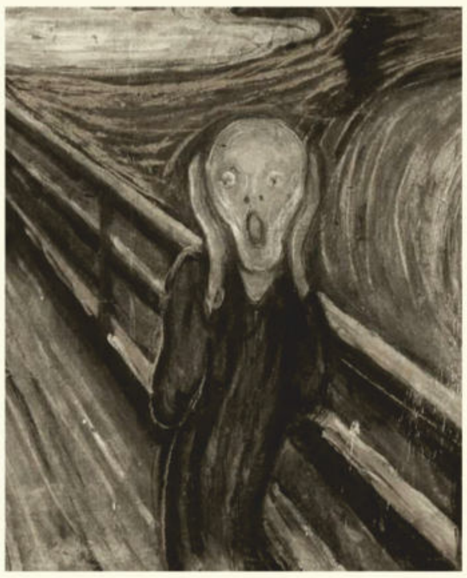
@PA4Claire

Waking up with that feeling of dread when everything is OK, and having to face the day while you're quaking inside... the trials and tribulations of living with #anxiety #AnxietyFeelsLike #MentalHealthAwareness #BeGentleWithYourself

Mer (semi-hiatus)

@marikuroros

#AnxietyFeelsLike Complete self sabotage. Constantly over analyzing nearly every aspect of your life and feeling like you're always being judged. Ruining relationships and great opportunities for success.



#CHEOPS

On 18 December, the European Space Agency's CHEOPS satellite was successfully launched from the spaceport in Kourou, French Guiana. It will now orbit the Earth and observe distant exoplanets with the aim of finding any that are habitable.

Ellen Stofan

@EllenStofan

Congratulations @esa on the launch of #Cheops! This mission will help us better understand #exoplanets – searching for possibly habitable worlds beyond our Solar System.

Stéphane Israël

@arianespaceceo

Extremely happy to orbit the Characterising Exoplanet Satellite (#CHEOPS) for our friends at @esa and @AirbusSpace. Flight #VS23 is the 52nd mission launched for the European Space Agency (as well the 128th satellite produced by #Airbus). #MissiontoSuccess.

#COP25

COP25, the longest United Nations climate talks on record, took place in Madrid at the beginning of December. The talks were unable to reach a consensus on many points and several key decisions have been pushed back to the next meeting, scheduled for November in Glasgow.

Dr. Katharine Wilkinson

@DrKWilkinson

Science makes me smile. Silence, not so much. Among #COP25 failures that really gut me: polluting countries blocking acceptance of @IPCC_CH's 1.5C report. But the truth still holds. We need the best climate science informing policy & action. #MarchForScience #ScienceNotSilence

COP25
CHILE
MADRID 2019

KEEP IN TOUCH

@SCIENCEFOCUS

ATHLETES

Taking up a sport can give your brain cells a boost, according to a study carried out at Northwestern University, Illinois. The brains of athletes can damp down background noise, allowing them to concentrate on relevant sounds more effectively, the researchers say.

CHILLI EATERS

Regularly consuming spicy peppers may help to cut the risk of heart attack or stroke, Italian researchers have found. A study of nearly 23,000 participants found that the risk of dying from a heart attack is 40 per cent lower in chilli eaters, while the risk of dying from cerebrovascular complications is halved.

Good month

Bad month

YOUNGSTERS

A study at the University of California has found 'meaning in life' peaks at age 60. When you're young, you are unsure about your career, your relationships, and who you are as a person, and you are searching for meaning in life. But as you get older, the search decreases and the meaning in life increases.

MOBILE PHONE ZOMBIES

Facial cuts, bruises and fractures are a surprisingly common result of owning a mobile phone, a study by plastic surgeons at Rutgers New Jersey Medical School has found. Many of the injuries were the result of texting or reading texts while walking, then tripping over an obstacle and landing face down. Ouch.

GETTY IMAGES X6 ILLUSTRATIONS: CHIARA BRAZZALE

ZOOLOGY

Secrets of orangutan 'language' uncovered

While they may not be as talkative as King Louie, it turns out that wild orangutans have some serious communication skills. Researchers at the University of Exeter have identified 11 vocal signals and 21 physical 'gesture types' that the apes use to communicate with one another. The findings reveal orangutans are responsive to communication, reacting either before gesturing ended, or in less than a second, in 90 per cent of communications.

The team studied video footage of 16 orangutans consisting of seven mother-child pairs and a pair of siblings, noting a total of 1,299 communicative signals – 858 vocal signals and 441 gestures.

The sounds included: the 'kiss squeak', a sharp kiss noise created while inhaling; the 'grumph', a low sound lasting one or two seconds made on the inhale; the 'gorkum', a kiss squeak followed by a series of multiple grumphs; and the self-explanatory 'raspberry'. Gestures included beckoning, stamping, pushing out a lower lip, shaking objects and 'presenting' a body part.

The researchers identified eight goals or requests of the communications: 'acquire object'; 'climb on me'; 'climb on you'; 'climb over'; 'move away'; 'decrease intensity'; 'resume play'; and 'stop that'.

"Orangutans are the most solitary of all the apes, which is why most studies have been done on African apes, and not much is known about wild orangutan gestures," said University of Exeter scientist Dr Helen Morrogh-Bernard. "We spent two years filming more than 600 hours of footage of orangutans in the Sabangau peat swamp forest in Borneo, Indonesia. While some of our findings support what has been discovered by zoo-based studies, other aspects are new – and these highlight the importance of studying communication in its natural context."

More signals are likely to be identified in the future, the researchers say.

MONTHLY CONTRACEPTIVE PILL COULD BE ON THE WAY

The daily oral contraceptive pill revolutionised birth control when it was introduced to the UK in 1961, but since then the field has seen little innovation. That could soon change, because researchers at Harvard Medical School and MIT are working on a slow-release pill that only needs to be taken once a month rather than daily. The new pill features six arms that unfold once swallowed to prevent the pill from rapidly exiting the stomach. So far the pill has only been tested in pigs, but the team hopes to begin human trials in the near future.

In numbers

4 BPM

The heart rate (in beats per minute) of a diving blue whale, measured by a team at Stanford University.

80 PER CENT

The percentage of children aged 11 to 17 that get less than one hour of exercise a day, according to the World Health Organization.

23 TEASPOONS

The amount of sugar found in some festive drinks sold in high-street coffee shops.

PSYCHOLOGY

Bad dreams are made of this...

Having nightmares may help to prepare us for frightening situations, according to a study by the University of Geneva, University Hospitals Geneva, and the University of Wisconsin.

> “Dreams may be considered as real training for our future reactions”

There’s a huge amount that science still doesn’t know about dreaming. We know that everyone experiences REM sleep, but whether those who claim they never dream really don’t, or they do dream but just don’t remember after waking, isn’t clear. Nor is the mechanism by which dreams are formed in the brain entirely understood, never mind why it happens.

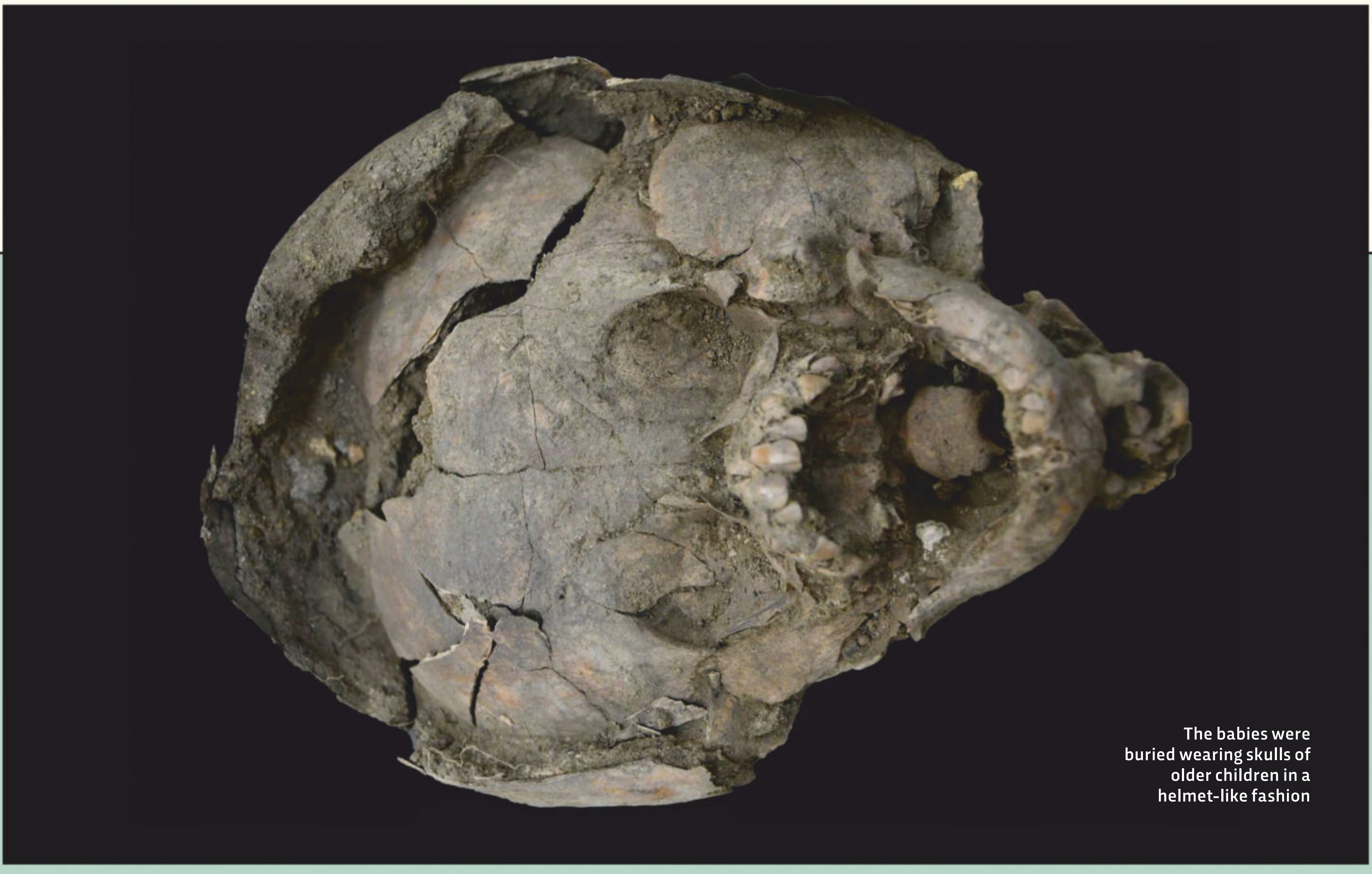
However, many neuroscientists have long believed that bad dreams allow us to ‘act out’ potentially dangerous situations before they occur in real life. And the new findings seem to add weight to that theory.

The researchers asked 18 volunteers to wear EEG headsets while they slept and then woke them multiple times during the night to ask them a series of questions about whether they’d been dreaming, and if that dream involved fear. They then compared the volunteers’ answers to their mapped brain activity during sleep. They discovered that during ‘scary’ dreams, two areas of the subjects’ brains were particularly active: the insula and the cingulate cortex. During the day, the insula is involved in identifying and evaluating emotional responses, while the cingulate cortex prepares the body’s physical reaction to perceived threats (the famous ‘fight or flight’ response).

In the second part of the study, 89 participants kept a ‘dream diary’ for a week, and were then shown a series of distressing images while lying in an MRI scanner. In subjects who reported having a lot of frightening dreams, the images triggered less of a response in the two brain regions studied, and in the amygdala – the brain’s ‘fear centre’ – than patients who reported few or none. What’s more, patients who’d had more bad dreams showed a greater amount of activity in the medial prefrontal cortex, a region of the brain that’s known to ‘dampen down’ the fear response.

“Dreams may be considered as real training for our future reactions, and may potentially prepare us to face real-life dangers,” said lead researcher Lampros Perogamvros, from University Hospitals Geneva.

Bad dreams are unpleasant, but they might help prepare us for real-life scary situations



The babies were buried wearing skulls of older children in a helmet-like fashion

HUMANS

Two babies from ancient Ecuador were buried wearing the skulls of other children as helmets

The skeletons were from a 2,100-year-old civilisation, and is the first discovery of its kind

In Salango, Ecuador, archaeologists from the University of North Carolina at Charlotte have unearthed the skeletons of two infants that were buried wearing the skulls of older children like helmets. The skeletons, which were roughly 2,100 years old, were found in burial mounds constructed by the Guangala people. This civilisation was based on the southwest coast of Ecuador, and dated from around 100 BC to 800 AD.

One of the infants is estimated to have been about 18 months old at the time of death, and was buried wearing the skull of a child aged between four and 12 years old. The other was between six and nine months old, and was buried wearing the skull of a child aged between two and 12. Both of the headpieces were fashioned from the neurocranium, or braincase.

"The fact that both layers of crania were made from juveniles struck me as particularly odd. Adult skulls were regularly manipulated in different ways in the pre-Hispanic Andes, but child skulls are less commonly involved," said research lead Dr Sara Juengst, an assistant professor at the university. "The skulls were fairly well preserved, although fragmentary from normal erosional processes associated with being buried. The outer skulls had straight edges, suggesting they had been cut, although only one cut mark was found."

It's unclear why the children were buried in this way, although heads were commonly depicted in the iconography, pottery and stone work of pre-Columbian South America, said Juengst. Children were also seen as being of special ritualistic importance by many Andean groups, such as in the Incan practice of sacrificing children on mountaintops. However, there isn't any evidence that the children here had been sacrificed.

The infants were buried just above a layer of volcanic ash, which likely indicates a volcanic eruption took place shortly before the burial. According to Juengst, this could have led to a loss of crops and eventual famine. This theory is backed up by both of the skeletons showing clear evidence of severe disease or malnourishment prior to death.

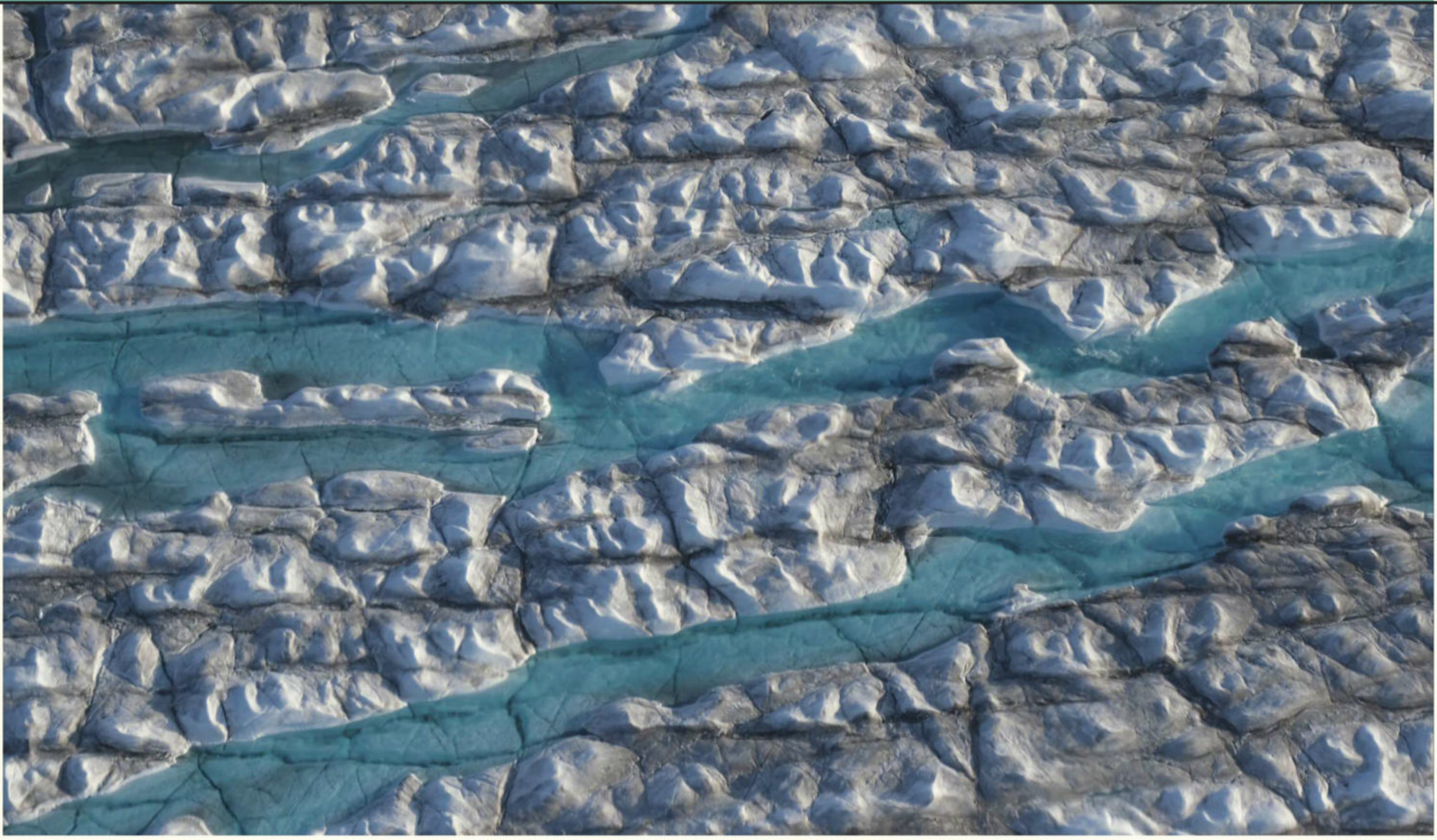
The researchers hope to use DNA samples from the remains to investigate any possible relationships between the infants and the skulls they are wearing.

GETTY IMAGES X2, SARA JUENGST

GREEN PAPERS

The environmental stories you need to know

Words: **Jocelyn Timperley**



ABOVE
A temperature rise of just half a degree could be all that's required to make the Greenland ice sheet start melting irrevocably

FUEL OVERREACH

By 2030, the world is set to burn over twice as much fossil fuel than the target needed to keep global temperature rises below 1.5°C, according to a report from the UN Environment Programme (UNEP). Scientists expect temperature rises above this limit would worsen the impacts of climate change, such as drought and flood risks.

The findings call for a "sharpened and long overdue focus on fossil fuels" wrote Inger Andersen, executive director of the UNEP, in the report's preface.

Countries could limit fossil fuel production by removing subsidies and aligning their production plans with climate goals, the report said.

CLIMATE CHANGE

Hotting up

New research suggests we may have already passed important climate tipping points

The world may have already passed several key climate "tipping points" and be in the process of passing others, according to a paper published in the journal *Nature*. The growing threat of these "abrupt and irreversible changes" to the climate must compel political and economic action on emissions, argue the researchers behind the report.

"If damaging tipping cascades can occur and a global tipping point cannot be ruled out, then this is an existential threat to civilisation," the paper says. "No amount of economic cost-benefit analysis is going to help us."

In just one of nine examples given by the paper, models suggest that the Greenland ice sheet, which is now melting at an accelerating rate, could pass a tipping point threshold at 1.5°C of warming – just half a degree above the 1°C of warming the world has already experienced.

"At some point the ice sheet's current state becomes unstable and passes a tipping point, as it does so the system

SUNLIGHT PRODUCES GREENER CEMENT

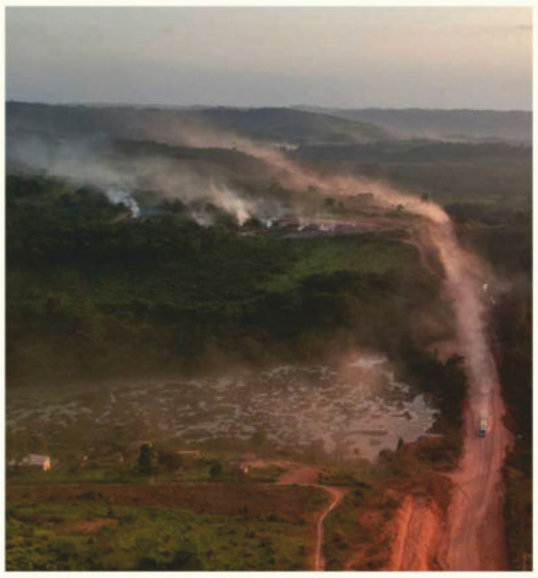
Heliogen, a clean energy firm backed by Bill Gates, has unveiled its solar technology intended to cut the carbon of heavy industry. The firm uses mirrors to concentrate solar energy and produce temperatures above 1,000°C. This sort of heat is required for steel and cement production, but viable low-carbon methods to generate it are hard to come by.

Heliogen's method will now be tested at a commercial scale. More work is needed to decarbonise cement production, however, since most of its emissions come from chemical reactions rather than heat.

starts transitioning irreversibly into the other state," explains Prof Tim Lenton, the report's lead author and director of the Global Systems Institute at the University of Exeter.

This alone could result in a sea level rise of seven metres, the paper says, while additional melting in the Antarctic ice sheet could increase this to 10 metres. Estimates of how fast this melting would happen range from thousands to tens of thousands of years, depending on how much temperatures rise above the 1.5°C threshold, the paper adds.

Another potential tipping point is the Amazon, which could reach a critical point where deforestation leads to an increased fire risk and climate feedback, according to the paper. This in turn would lead to yet more deforestation in a downward spiral.



Researchers have been discussing these potential climate tipping points for at least two decades, however it was initially thought they would only be breached with a global average temperature rise of 5°C or above. But more recent research suggests the tipping points could be exceeded with just 1-2°C of warming, according to the paper. This realisation "requires an emergency response," its authors state.

Lenton also says evidence is appearing of interactions between tipping points, which could lead them to trigger one another. "You put this evidence together in a sort of risk assessment framework and it becomes clear that we're running serious risks with climate change and these particular systems," he adds.

> **"We're running serious risks with climate change and these systems in particular"**

INSPIRED

CITY FARMS

Scaling up urban agriculture could help reduce food insecurity and poor nutrition in cities and suburbs, says a study by the American Society for Horticultural Science.

SMART MONKEYS

Endangered wild macaque monkeys in Morocco are cleverly adapting to their human neighbours, according to a recent study by the University of Lincoln. But with habitats still shrinking, this may only take them so far, it adds.

EXPIRED

RARE PLANTS

Over 35 per cent of the world's land plant species are "exceedingly rare", making them more at risk of extinction due to climate change, according to a study by the University of Arizona.

COAL BOOM

China's coal-based power production has increased by 43 gigawatts in the last 18 months, says NGO Global Energy Monitor – an expansion similar to Germany's total production.

IT'S EASY BEING GREEN

HELP WILDLIFE AT HOME

There are lots of ways you can support nature in your garden, says the RSPB. Planting a mix of herbaceous, biennial and annual flowering plants can benefit wildlife, for example. Single-petalled flower varieties are usually better for insects than those with multiple layers of petals.

Trees, shrubs and mixed-shrub hedgerows that provide berries for birds can be planted in the winter, as long as the ground isn't frozen or waterlogged. You can also help to monitor the UK's birdlife by taking part in the RSPB's Big Garden Birdwatch. The project asks people to spend an hour outside counting birds in late January.

GETTY IMAGES X6, BEN HALL/RSPB

SPECIAL REPORT

White Island volcano eruption: what happened?

On 9 December 2019 the volcano on White Island, about 50km away from the northeast coast of New Zealand's North Island, erupted explosively. Of the 47 people on the island at the time, 18 were killed and many more severely injured. White Island has been classified as New Zealand's most active volcano since 1976, when it began a period of 24 years of almost continuous eruption. A second period of eruption started in 2011 and continues today. Volcanologist Prof Bill McGuire takes us through what happened.

HOW MUCH OF A SURPRISE WAS THE WHITE ISLAND ERUPTION?

The eruption came as no surprise to volcanologists. Like Stromboli, which lies in the Tyrrhenian Sea off the western coast of Italy, Mount Etna on the eastern coast of Sicily, and Kilauea in Hawaii, White Island is a volcano that is almost continuously showing signs of activity. A feature that makes it very attractive to tourists.

The volcano has an open vent that is typically steaming or sending out jets of gas. Periodically, activity escalates, producing small to medium eruptions of ash, blocks and volcanic bombs – pieces of molten rock with diameters greater than 64mm. Before this most recent blast, the volcano had erupted five times in the last 20 years.

WHAT EXACTLY HAPPENED?

DOES THE WHITE ISLAND VOLCANO HAVE ANY UNUSUAL FEATURES?

1

2

White Island is actually two overlapping volcanoes poking out of the Bay of Plenty, 50 kilometres northeast of New Zealand's North Island. A major collapse of the crater wall in 1914 wiped out a sulphur mine on the volcano and killed those working there.

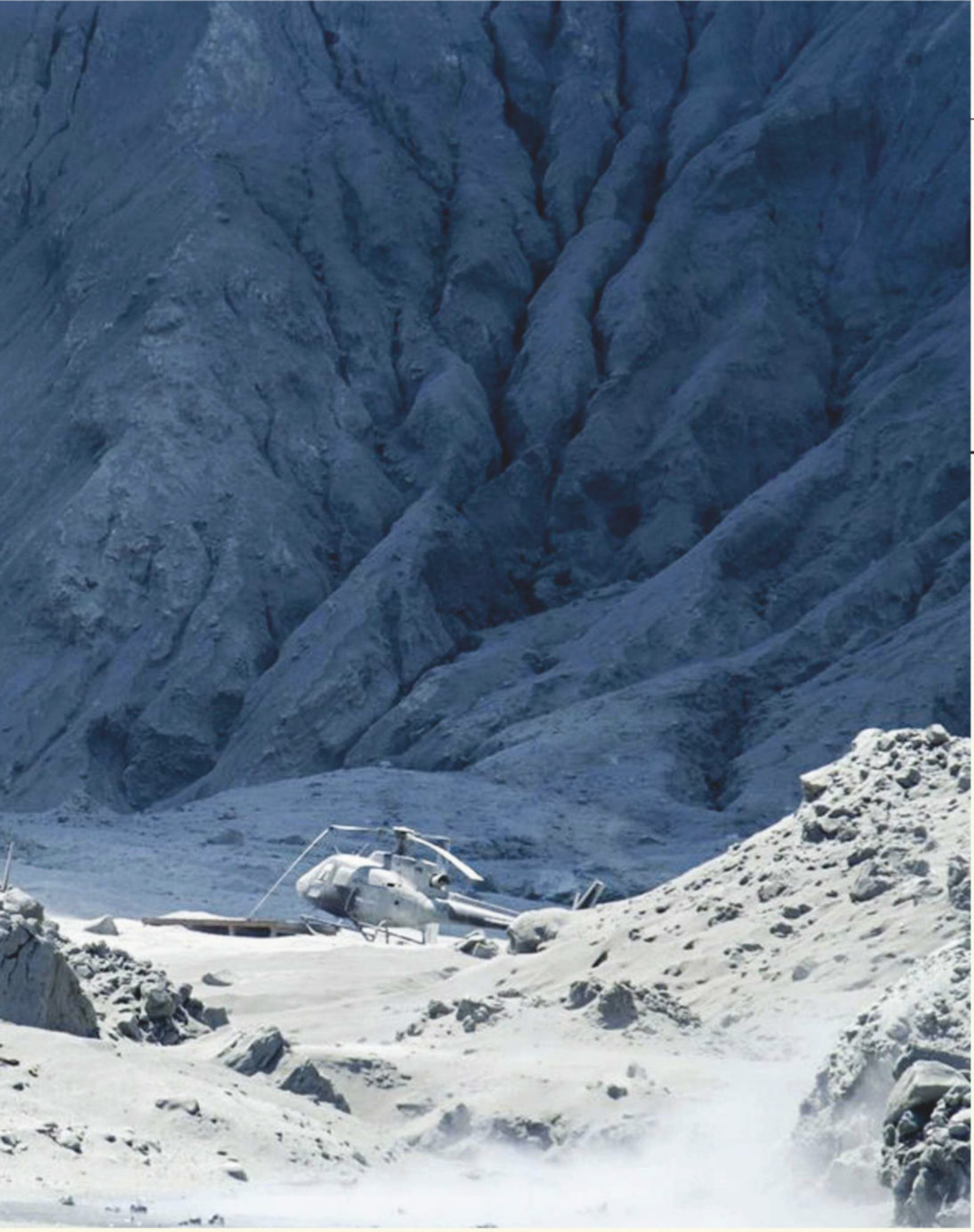
The most recent eruption was caused by rising magma coming into contact with groundwater, resulting in a violent but short-lived – just 12 minutes – hydromagmatic blast [a violent combination of water and magma] that sent a cloud of ash up to four kilometres into the atmosphere. At the same time, ground-hugging clouds of steam, hot ash and rock poured rapidly across the terrain.

WERE THERE ANY WARNING SIGNS?

Yes. There were clear signs that an eruption of some sort might have been on the way.

3

> "There were clear signs that an eruption of some sort might have been on the way"



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White Island had shown signs of becoming increasingly restless since at least October, with a rise in sulphur dioxide gas emissions and elevated levels of ground tremors. The alert level was raised from 1 to 2 on 15 November and by early December the volcano was producing violent jets of gas, as well as ejecting mud and debris up to 30 metres into the air. [Volcano alert levels go from 0 (no volcanic unrest) to 5 (major volcanic eruption).]

WHAT MAKES VOLCANO ERUPTIONS SO DIFFICULT TO PREDICT?

Provided volcanoes are being monitored, their eruptions are not difficult to predict. To reach the surface, magma must break rock, which generates swarms of small earthquakes detectable by seismometers. Magma also causes the ground to swell, which can be measured using GPS and similar techniques.

Often, the rates of increase of earthquakes and ground swelling can be used to estimate the start of an eruption. But predicting the exact timing of small hydromagmatic blasts, like the one at White Island, is notoriously difficult.

IS IT SAFE TO VISIT ANY VOLCANO AS A TOURIST?

No volcano is completely safe, either for the volcanologists working on it or for tourists who are just visiting. Most tourists want to see some sign of activity, and this is the problem. The volcanoes that tourists visit most – White Island, for example – are more active. This means that the risk of an eruption causing injury or death is higher.

1. This shot, taken by the Auckland Helicopter Trust, shows the White Island volcano erupting

2. A rescue team was quickly dispatched to the scene

3. This helicopter was thrown from its launchpad and covered in ash by the blast

4. This shot was taken by visitor Michael Schade moments before the volcano erupted

PRESS ASSOCIATION X3, SHUTTERSTOCK

by **PROF BILL MCGUIRE**
Bill is emeritus professor of earth sciences at University College London.

NATURE

SCIENTISTS IDENTIFY 71 NEW SPECIES

In 2019, the California Academy of Sciences, the US equivalent of London's Natural History Museum, described a multitude of new species, spanning five continents and three oceans. Here are some of the most intriguing specimens they added to the tree of life.

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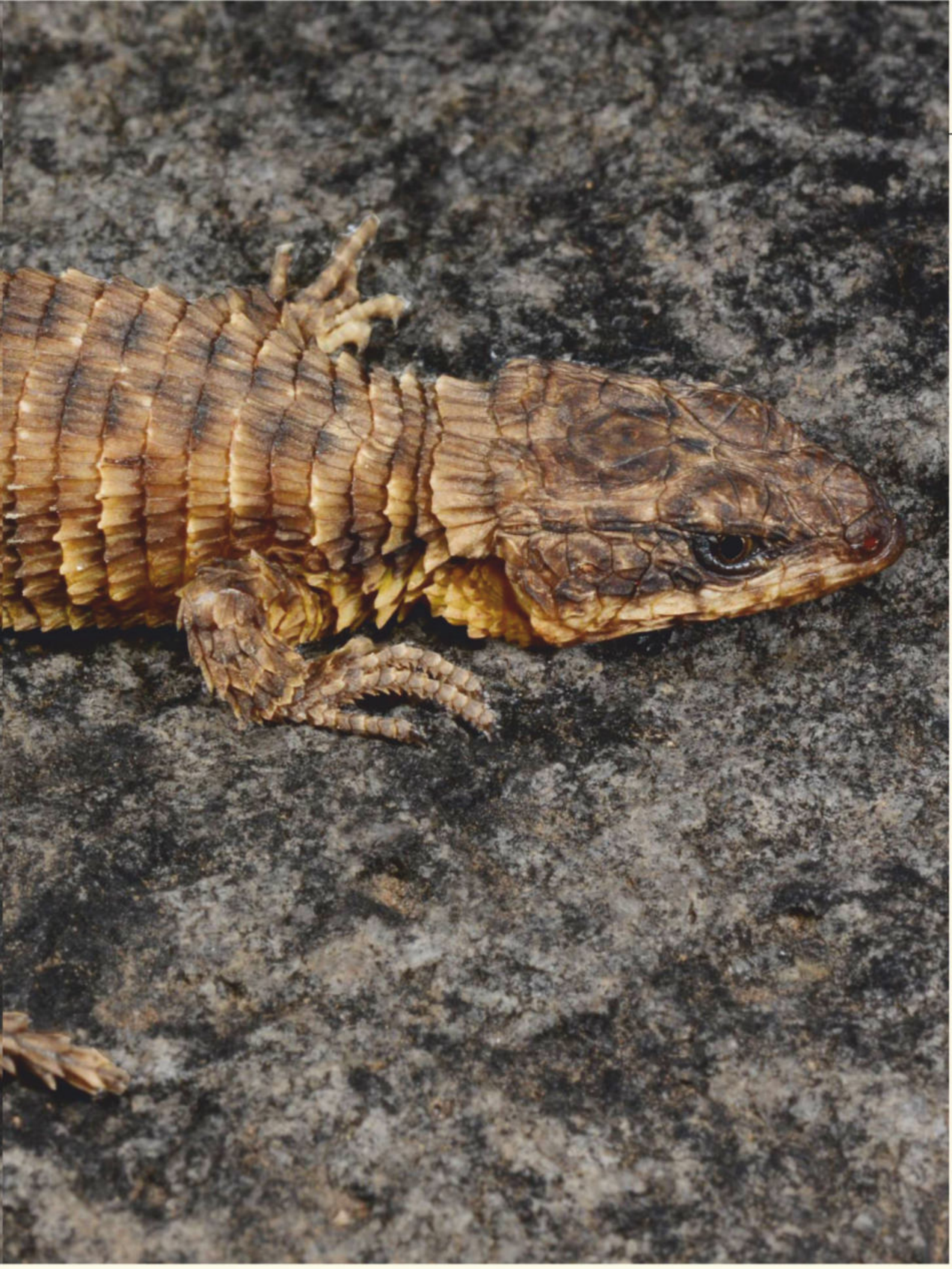

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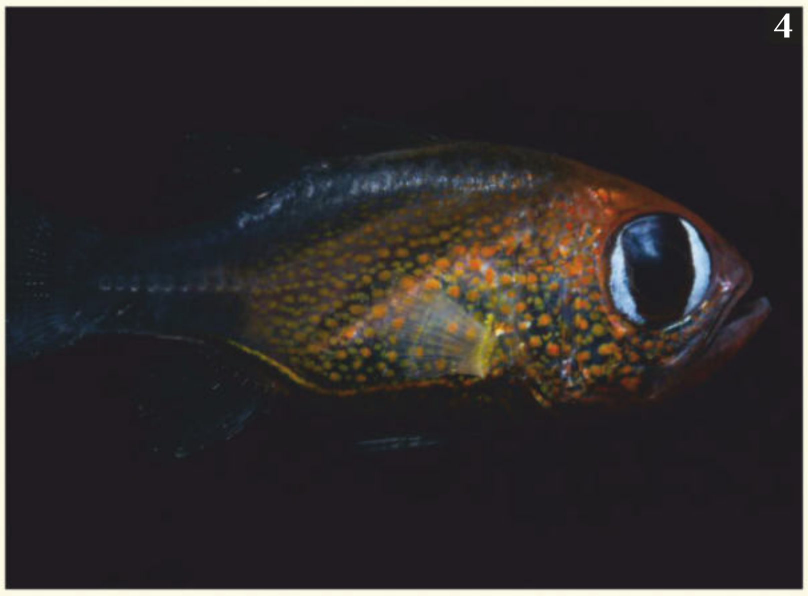

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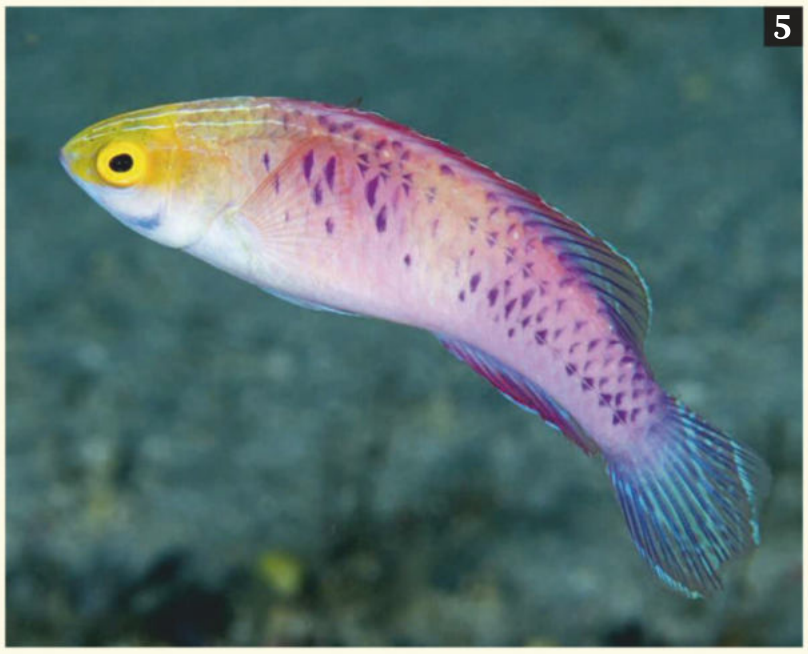

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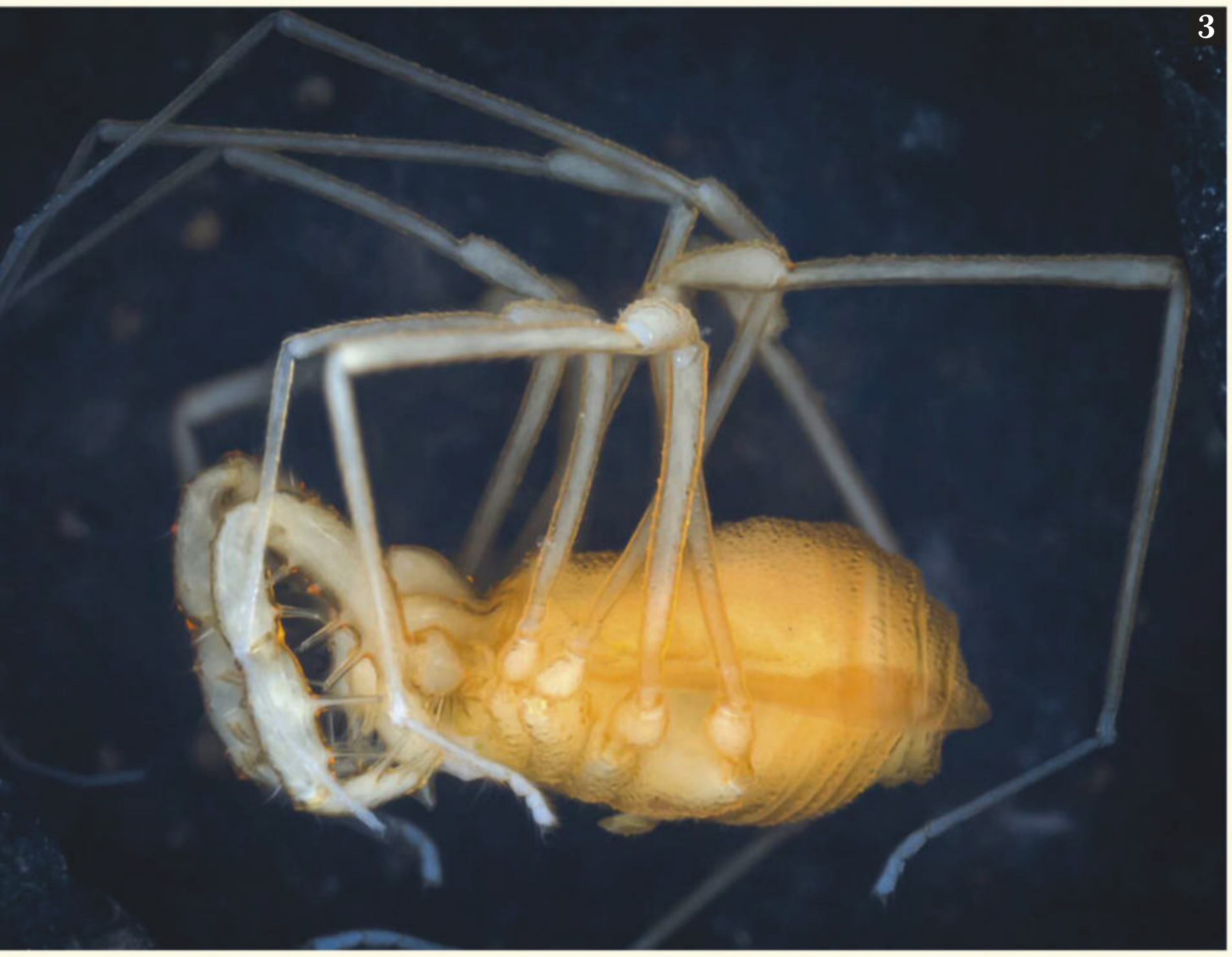


1. This girdled lizard (*Cordylus phonolithos*) is found on Serra da Neve Inselberg, Namibe Province, southwestern Angola.

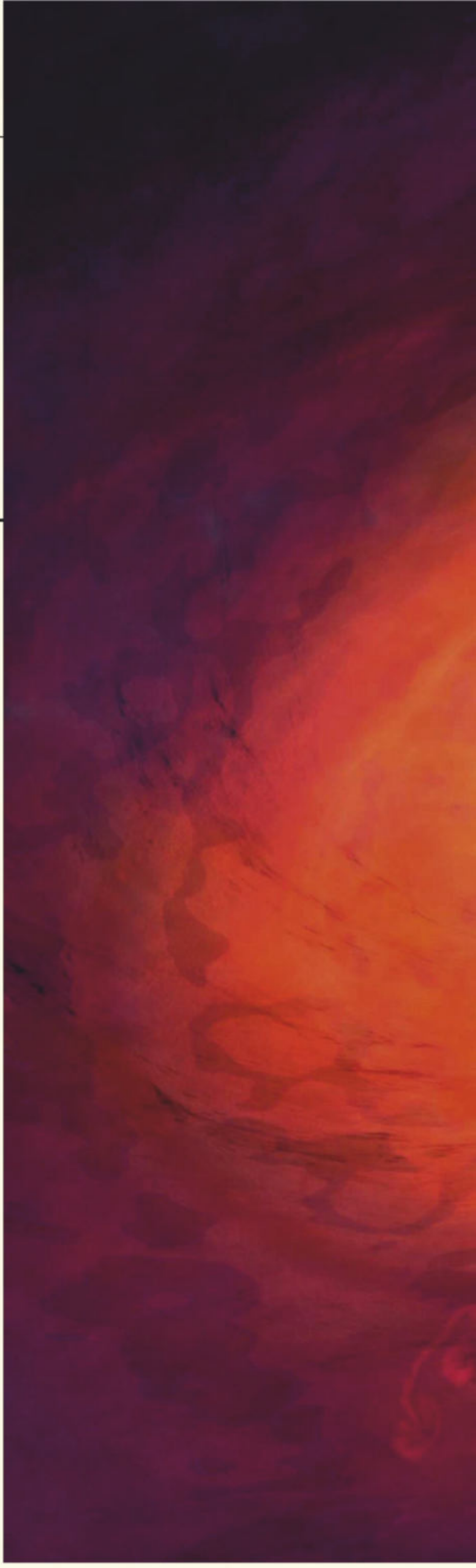
2. This dazzling sea slug species (*Janolus tricellariodes*) is found in the Philippines.

3. This cave-dwelling harvestman (*Lola konavoka*) is adapted to life in the dark. It is found in Croatia and is already critically endangered.

4. This cardinalfish species (*Siphamia arnazae*) has giant, cat-like eyes and is found in Papua New Guinea.

5. This colourful, shimmery fish (*Cirrhilabrus wakanda*) was named the 'vibranium fairy wrasse' after the fictional metal found in the Marvel Universe that was used to construct Captain America's shield and Black Panther's suit. Its Latin name is a reference to the fictional country of Wakanda – home of Black Panther. The fish was discovered at a depth of 60 metres in the ocean off Zanzibar, Tanzania.

Dr Dejan Stojkovic professor of cosmology



ABOVE Could the black hole at the centre of the Milky Way actually be a wormhole? Researchers are trying to find out

Horizons

Is there a wormhole hiding at the centre of the Milky Way?

Many people believe wormholes only exist in the realm of science fiction. But some astronomers think these phenomena could be real. To find out for sure, a group of researchers based in China and the US are looking at objects near Sagittarius A*, the supermassive black hole at the centre of our Milky Way. The aim is to find out whether the black hole might actually be a wormhole instead. Dejan Stojkovic, of the University at Buffalo, New York, is taking part in the research

WHAT IS A WORMHOLE?

A wormhole is an object connecting two distant parts of the same universe, or two different universes altogether. It is a hypothetical object that has never been observed so far, but it is a legitimate solution to Einstein's equations. As such, there is a great chance that it is realised somewhere in nature.

HOW DID YOU GET INTERESTED IN WORMHOLES?

In my research, I always pay most of my attention to interesting problems at the very boundary of our knowledge. Wormholes certainly fit into this description.

CAN YOU EXPLAIN YOUR NEW TECHNIQUE FOR FINDING THEM?

A traversable wormhole allows for particles and fields to travel through it. Gravitational perturbations caused by massive objects on the other side of the wormhole would affect the motion of objects, for example stars, on our side. We calculated these perturbations and applied them to the motion of stars we observe around the centre of the Milky Way [where the supermassive Sagittarius A* black hole is located].

HOW WOULD STUDYING THE STARS AROUND A BLACK HOLE HELP DETERMINE WHETHER THERE IS A WORMHOLE?

A black hole has a point of no return, called an 'event horizon', and something called a 'singularity' [a point of infinite density] at the centre. A wormhole is regular and allows for a smooth travel from one side to another. Since we cannot send probes and spacecraft through a wormhole or a black hole in order to see the difference, the only way to distinguish them is to observe motion of objects around them.

GETTY IMAGES

> "A traversable wormhole allows for particles and fields to travel through it"

IN YOUR WORMHOLE RESEARCH, YOU STUDIED THE STAR S2, WHICH IS ORBITING SAGITTARIUS A*. WHY DID YOU PICK THIS STAR?

It is the best-studied star orbiting what is believed to be a supermassive black hole at the centre of the Galaxy. We know the motion and orbit of S2 with great precision. Deviations from the expected orbit could indicate that the supermassive central object might be something as exotic as a wormhole.

HOW DOES A WORMHOLE STAY OPEN?

You need some form of repulsive gravity to prevent its collapse. Either some exotic form of negative energy density, or some elaborate setup that serves the same purpose: to provide repulsion.

WHAT'S NEXT FOR YOUR RESEARCH?

The gravitational perturbations of S2 could be caused by some other invisible objects on our side, say smaller black holes. If the deviations are observed, we would have to do more careful modelling to pinpoint the source of perturbations. That is what we are concentrating on right now. I expect that within a decade, we will have the necessary precision to exclude the most generic wormhole scenario for the centre of the Galaxy. This, however, would not exclude their existence somewhere else in our Universe. The same techniques we proposed can be applied to any other black hole and star binary system.

DR DEJAN STOJKOVIC

Dejan is a cosmology professor at the University at Buffalo, New York. ***Interviewed by science writer Abigail Beall.***

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REALITY CHECK

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Climate change language | Mental health apps | Nostalgia

WE MIGHT BE FANTASY
CLIMATE CRISIS IS NOT

REVIEW

CLIMATE CHANGE: SHOULD WE CHANGE THE TERMINOLOGY?

Could terms like 'climate collapse' and 'global meltdown' do a better job of altering our behaviour?

"We need people to call their MPs, change the way they vote, change their behaviour ... language plays an important role in that"

BBC *Visit the BBC's Reality Check website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

DECLARE CLIMATE & ECOLOGICAL CRISIS

LEFT Just like these protesters, *The Guardian* is now using the term 'climate crisis' rather than 'climate change'

ABOVE People taking part in global climate strikes in New Delhi, India

WHAT OTHER TERMS FOR CLIMATE CHANGE HAVE BEEN SUGGESTED?

In May 2019, *The Guardian* announced that it was changing the language used around environmental issues. The key difference is that it will no longer use the term 'climate change', instead referring to the 'climate crisis'. This followed the UN's secretary general António Guterres use of the term in a speech in September 2018.

At the same time, *The Guardian* dropped 'global warming' in favour of 'global heating' and replaced 'biodiversity' with 'wildlife', among other changes. The move to 'global heating' is supported by Prof Richard Betts, climate scientist at the Met Office, who recommended the change while speaking at the UN climate summit in December 2018. Then, in November, branding expert Aaron Hall challenged a team of marketers to come up with alternative terms for climate change that would inspire people to take action and change their behaviour. The names they came up with included 'climate chaos', 'global meltdown', 'Scorched Earth', 'The Great Collapse' and 'Earthshattering'.

WHY CHANGE THE TERMINOLOGY?

Katharine Viner, the editor-in-chief of *The Guardian*, said that the term 'climate change' doesn't accurately communicate the real danger we are in. "What scientists are talking about is a catastrophe for humanity," she says.

The choice of language can have a profound impact on an audience's reaction to an idea. "Some people say: 'how much does language really matter? We need people to call their MPs, change the way they vote, change their behaviour.' But I do think language plays an important role in that," says social psychologist Dr Sander van der Linden, director of the Cambridge Social Decision-Making Lab. For example, the term 'climate change', while scientifically accurate, doesn't necessarily communicate that regular people actually need to do anything. "Just because something is changing, it doesn't mean it requires any action from me. That doesn't signal action," he explains.

"Changing the way we talk about climate change is key to getting people to act," says Dr Dann Mitchell, associate professor in atmospheric science at the University of Bristol. He highlights the discussion of global average temperatures as an example where this is particularly important. "If you were to get in a bath that was 0.2°C warmer than it was when you got in the same bath 10 years ago, you wouldn't care, or even know. But for the Earth-system as a whole, this small temperature change has huge repercussions, because it can be significantly amplified at local levels."

The term 'global warming' could be considered misleading, says van der Linden, because the effects are far broader than just warming temperatures, and also include flooding and a loss of wildlife. "On the one hand, people are saying that global warming is more emotive and can be more persuasive," van der Linden explains. "On the other hand, it might miss out on getting people concerned about the whole range of impacts."

DOES CHANGING LANGUAGE EVER CHANGE BEHAVIOUR?

In medicine, it is well known that language strongly influences patients' feelings about a particular procedure

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CLIMATE
EMERGENCY
GREENPEACE

ABOVE Ahead of December's European Summit to fund the fight against climate change, activists protested on the European Council's building in Brussels

or illness. "If you frame something to a patient as probability of death versus survival, even though the probability is the same in both scenarios, people have very different responses to that, just based on the wording," says van der Linden.

This framing effect can be harnessed to encourage people to take more environmentally friendly actions. In a 2008 paper, social psychologist Noah J Goldstein and team investigated whether guests at a hotel were more likely to reuse their towels based on how the request was framed. If the guests were told to 'help save the environment' by reusing towels, then 35 per cent of them took part. This rose to 44 per cent reusing their towels when told that the majority of guests already did. This number increased to 49 per cent if they were told that the majority of guests who had stayed in the same room as them took part.

How we talk about the climate seems to matter when it comes to influencing others. Speaking to 6,000 Americans, van der Linden's own research found that explaining the idea of scientific consensus, in a clear and simple manner, significantly changed their beliefs about climate change and even affected how worried they were about it.

Climate change language has changed before. A South Korean paper studied over 40,000 tweets containing the terms 'global warming' and 'climate change', spanning from 2004 to 2015. The researchers found that, over time, 'global warming' had gradually become less popular, with 'climate change' taking its place.

WHAT IS THE BEST TERM TO USE?

What term you should use depends on the context, and what you're trying to get across. Mitchell believes that while 'climate crisis' might be appropriate for a publication like *The Guardian*, as a climate researcher, he should only use impartial language. "'Anthropogenic climate change' is about the only term I use, often just shortened to 'climate change'," he explains. "As a scientist, accurate scientific terminology is always our only choice. So, while the term 'climate crisis' seems not quite right, it is clear why it is being used, and frankly I don't think a word exists for exactly what type of emergency this is."

When it comes to communicating with the public, however, it's important to choose terms that invoke the right emotions. Namely, people need to be worried. "[Worry] is an active emotional state in which people cognitively engage in thinking about a problem and how they might avoid it, versus fear, which is more of a paralysing emotion," says van der Linden. So, the ideal term conveys a sense of both urgency and optimism, and not a sense of doom.

'Climate crisis' is van der Linden's choice, at least of the ones he has heard so far. "Global meltdown, I think, sounds too catastrophic. Chaos is not something people like. Chaos is uncontrolled," he says. "I think 'climate crisis' signals an urgency. People don't like crises either, but people know that crises can be avoided and that they can be resolved."

by SARA RIGBY

Sara is online assistant at BBC Science Focus.

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ANALYSIS

SMARTPHONE APPS: CAN THEY IMPROVE OUR MENTAL HEALTH?

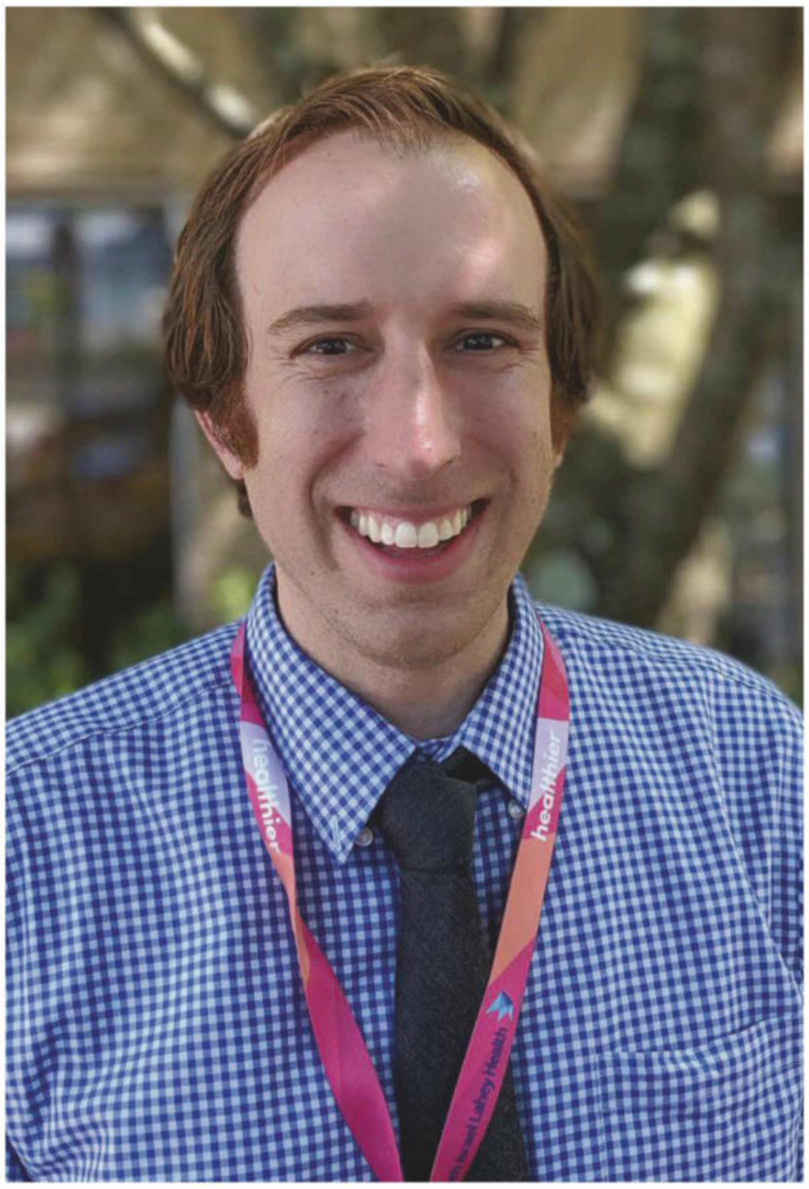
Mental health apps are everywhere. But do they actually help us?

When it comes to mental health, smartphones usually get a bad rap – studies have linked their overuse to loneliness, depression and sleep deprivation.

But there's also a growing wellbeing movement built around our phones. A search for 'mental health' on the App Store or Google Play throws up hundreds of apps geared towards every aspect of our mental health. There are apps that assess and diagnose our state of mind; apps that allow us to track our feelings and thoughts; apps that provide coping tools such as meditation and cognitive behavioural therapy; and even therapy chatbots.

According to an NHS Digital survey from 2014, around one in six of us experiences depression or an anxiety disorder in any given week. With mental health services increasingly stretched, can these apps provide support to people who are unable to – or don't want to – access conventional therapies?

"Every country in the world has limited access to mental health care, and these apps have the potential to deliver evidence-based treatment to the right people at the right time," says Dr John Torous, director of the digital psychiatry division at Beth Israel Deaconess Medical Center in Boston, Massachusetts, and leader of the American Psychiatric Association's work group on the evaluation of smartphone apps. However, Torous emphasises the word 'potential'. There is



Digital psychiatry: what's in store?

MindLAMP is an app in development that could help extend psychiatric help beyond the therapist's office

currently little evidence that these apps can be an effective replacement for standard therapies. In a paper published in December last year in the journal *npj Digital Medicine*, psychologists in Germany and the Netherlands carried out a meta-analysis of 19 studies that looked at the effectiveness of various mental health apps. The researchers concluded that "using smartphone apps as standalone psychological interventions cannot be recommended based on the current level of evidence".

FEELING 'APPY?

Torous says that mental health apps are most useful when they're combined with conventional therapy and professional guidance. In another meta-analysis published last year, researchers in Australia, Sweden and the Netherlands found that the effectiveness of smartphone apps in treating depression doubled when guidance was provided by therapists or research staff. "The apps are best used to augment, extend and expand care, not to replace it," says Torous.

However, Torous doesn't believe we should stop downloading mental health apps altogether. They *can* be helpful on an individual basis, he says, provided we choose them wisely and use them mindfully. They can be a first step towards getting help, for instance, or a useful stopgap for those waiting for treatment.

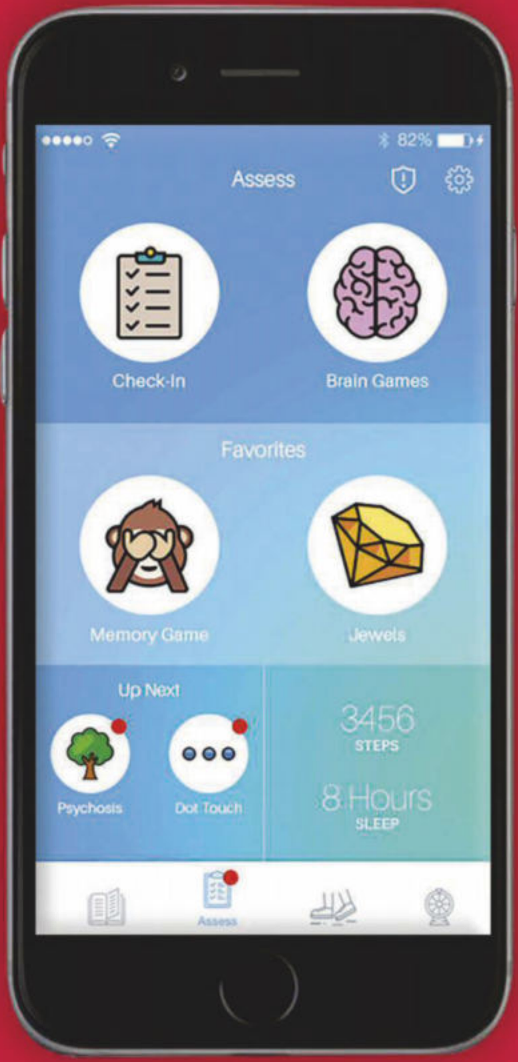
So how to choose a mental health app? In some cases, apps can offer incorrect advice, potentially putting people at risk. And they often make claims that simply don't stand up to scrutiny. Last year, for example, Torous and colleagues at the University of

> **"The potential of these apps to increase access to care and offer tools in the palms of our hands is so powerful that it's going to keep driving innovation. There's nothing else that can reach that many people"**

A smartphone app being developed by psychiatrist Dr John Torous and colleagues at Beth Israel Deaconess Medical Center offers a glimpse into the future of digital psychiatry.

The *mindLAMP* app uses a variety of methods to monitor a user's mental health. Surveys allow the user to report their symptoms; brain games test the user's cognitive abilities, such as memory and attention; and a tagging feature allows the user to record who they are with, and where. The app can link in with Google Fit and Apple HealthKit, collecting data such as step count and heart rate, and it also provides mindfulness games to help users manage and reduce their symptoms.

In a study published last September, participants with psychosis used the app for three months. By analysing the data, Torous and colleagues could pick out some useful correlations. For example, one participant's survey scores for depression, anxiety and psychosis began to decrease when she kept to her medication schedule.



Another participant's depression, anxiety and psychosis scores were found to reduce when she had a better night's sleep.

"Our initial findings provide evidence that use of a smartphone application to monitor symptoms and behaviours produces an individual pattern for each person, indicating that this is a feasible means of monitoring and detecting patient status," write the researchers, adding that this could help to provide personalised treatment plans.

The variation in individual experiences meant that it wasn't possible to pick out broader correlations between lifestyle and mental health, but more studies with the app (which has been made open-source so that other institutions can use it) could change that.

The app is currently only available to those who are taking part in a study, but the researchers plan to make the app freely available once the initial studies are complete.

ABOVE LEFT Psychiatrist Dr John Torous says mental health apps can offer a first step towards getting help

New South Wales in Australia analysed app store descriptions of 73 high-ranking mental health apps for Android or iOS. Only one app directly referenced a scientific study to back up its claims.

APP ADVICE

Torous has three main pieces of advice. "Look for apps that have been updated within the last 180 days," he says. "If an app hasn't been updated, it might be because the developers aren't keeping up to date with medical information. Also, look for apps from developers that you've heard of and trust."

Check whether the app has a privacy policy. "If it doesn't, that's a red flag," he says. "The app may be free, but are you paying for it with your personal health information? You're sharing sensitive information with these apps, so you need to understand what's happening to your data and what you're agreeing to. It's all about trust – these apps have to show us why we should be open to sharing our intimate details with them."

A good place to start for health apps, says Torous, is the NHS Apps Library (**nhs.uk/apps-library/**). The apps featured here have all been approved following assessment for a number of different factors, including effectiveness, security, and technical stability. At the time of writing, there are 20 apps in the library geared towards mental health.

Once you've downloaded an app, Torous advises telling a family member or friend. "Mental health apps have a higher chance of being helpful if you can stick with them," he says. "And one of the best ways of sticking with them is to let someone know, so that they can check in with you and keep you accountable. Don't go it alone."

Ultimately, it's still early days for these apps. The field of psychiatry has been developing for centuries; many of the apps designed to help our mental health have appeared in the last five years or so.

But Torous is confident that the apps will improve. "The evidence may not be there yet," he says, "but the potential of these apps to increase access to care and offer [therapeutic] tools in the palms of our hands is so powerful that it's going to keep driving innovation. There's nothing else that can reach that many people."

by **JAMES LLOYD**
James is staff writer at BBC Science Focus.

COMMENT

NOSTALGIA: WHY DOES THE PAST LOOK SO ROSY, AND DOES IT BLIND US TO NEW EXPERIENCES?

An onslaught of remakes and reboots proves that people love the past. Neuropsychologist Catherine Loveday explains why looking back can be good for us

Nostalgia is big business these days. With sequels, prequels and spin-offs hitting our screens, it seems that film and TV studios know exactly which heart strings to tug at to get us to spend our money. Just take a look at *Star Wars* spin-off *The Mandalorian,* which premiered on Disney+ at the end of last year. Analytics firms have described *The Mandalorian* as the most in-demand series in the world. So why does nostalgia hold so much power over us?

DO YOU REMEMBER WHEN… ?

Feelings of nostalgia play an important role in creating and maintaining relationships. Many of us know what it is like to bond over a shared reminiscence for music, comedy or even television adverts. What is particularly striking is how positive those feelings and memories tend to be. Studies show that when younger and older adults are asked to remember past experiences, the older adults tend to recall the positive events, like holidays and special occasions. Younger people, though they can recall positive events, are far more likely to remember negative things, such as accidents and stressful events. Scientists believe that this shift reflects a change in goals. Young adults are strongly oriented towards exploration and learning, which necessitates reflecting on the mistakes we have made. But as we grow older and the time ahead of us shrinks, we become more present and focus instead on savouring the good things.

> “We share a tendency to prefer the music, books, films and famous people that we first encountered during our teenage years”

Research also shows that we share a tendency to prefer the music, books, films and famous people that we first encountered during our teenage years. A popular explanation for this so-called ‘reminiscence bump’ is that these cultural experiences become intrinsically linked to important personal memories, like leaving home, that relate to our sense of self and our relationships with others. People seem to be particularly attached to songs and films that remind them of a significant person, or of a key turning point in their life. According to Dr Petr Janata from the University of California, this is because lifetime memories are actively linked with music by the ‘medial prefrontal cortex’, an area of the brain that enables us to recognise experiences that are meaningful and relevant.

GOOD OR BAD

Over the years, there have been many different views on the benefits and pitfalls of nostalgia. In fact, in its earliest descriptions dating back to the 17th Century, nostalgia was seen as a medical condition that indicated brain dysfunction. Over time, the definition has taken on a different meaning, depending on the individual and the context in which it occurs. For example, some people are shown to be more prone to nostalgia and it is these individuals that benefit the most, showing greater optimism and self-esteem after they have been encouraged to reflect on past events.

So, should we put off going to see the new *Star Wars* film, *The Rise Of Skywalker*?

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There's no harm in revelling in nostalgia, as it can have positive effects

Is there a danger to being too nostalgic? For a small number of people, the answer is probably yes. One study showed that although inducing nostalgia in the lab has a positive effect on most people, it can lead to distress in those who are prone to worrying and rumination. This seems to be because being nostalgic heightens their sense of loss of the past. For these individuals, activities and therapies that focus on the present may be more valuable.

By and large, though, nostalgia has been found to have incredibly positive effects. It boosts motivation, promotes more cooperative behaviour, improves mental health, encourages optimism, reduces loneliness and raises self-esteem. Contradictory to expectations, feeling nostalgic can enhance our openness to new experiences and foster creativity. It has even been shown that inducing a pleasant nostalgia can make the weather seem less gloomy. So, next time the skies cloud over or you find yourself feeling a bit down, invite a friend over and pull out the DVD of *Star Wars: A New Hope*. A little trip down memory lane can do us the world of good. **SF**

by **PROF CATHERINE LOVEDAY**

Catherine is a neuropsychologist at the University of Westminster. She often appears as an expert on BBC Radio 4's All In The Mind, *and is the author of* The Secret World Of The Brain *(£9.99, Andre Deutsch Ltd).*

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↗ One of these will make our commute a whole lot more fun p44

INNOVATIONS

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↗ Glass skyscrapers have a big carbon footprint, but if their windows could be converted into solar cells, then they could get their energy needs from sunlight

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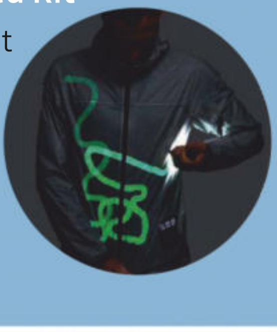


GoSun Solar Chiller

This coolbox uses the Sun's rays to keep your food frosty. If the clouds roll in, the powerbank inside will keep the box running for 14 hours.

Logitech Wireless Solar Keyboard

Reminiscent of the solar-powered calculators of yore, the cells on this wireless keyboard mean you'll rarely, if ever, need to replace the batteries.

FIRST LOOK

Transparent solar cells could replace office windows

It's possible to punch tiny holes in photovoltaic cells to make them see-through

Conventional solar cells can be rendered see-through by puncturing them with holes thinner than the width of a human hair. The team behind the breakthrough hopes that the tech could one day be used to build office blocks that are powered by their windows.

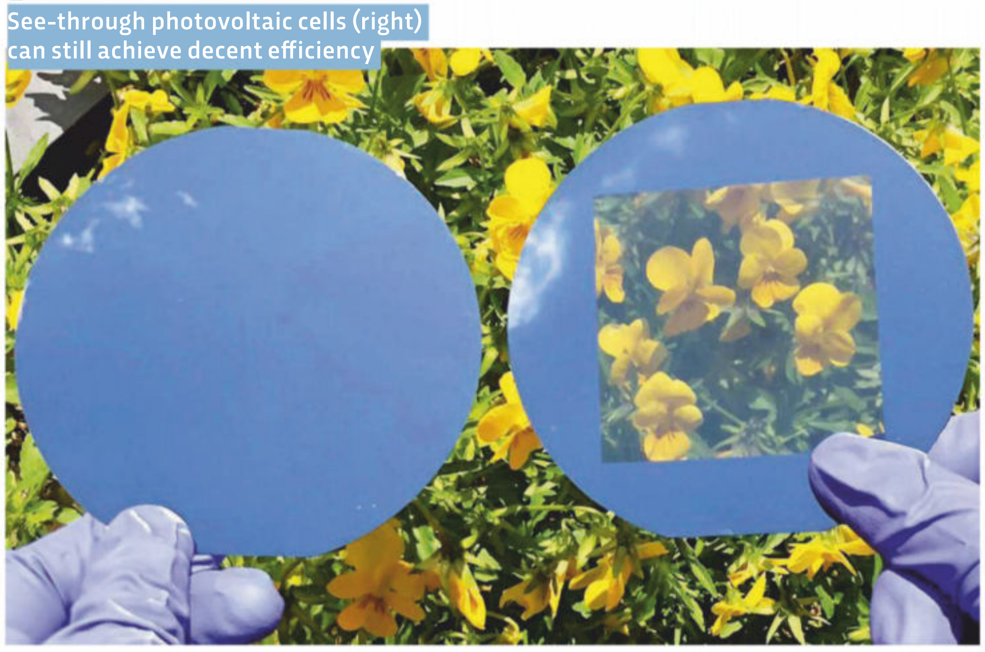
Most solar cells sat on top of household roofs are opaque. The darker they are, the better they absorb solar energy. They're mostly made out of a glass-like material called crystalline silicon, which is stable and efficient. Filling the surface area on top of a house with these cells can provide enough energy to power what's inside, but the same isn't true of a tower block or skyscraper where the roof is only a small proportion of its surface area.

To remedy this problem, researchers at South Korea's Ulsan National Institute of Science and Technology have been searching for a way to create windows that can harvest the Sun's energy, as it could drastically reduce the carbon footprint of these energy-hungry buildings.

The team discovered that if they punched tiny holes into crystalline silicon cells, in patterns undetectable to the human eye, they could render them as transparent as tinted glass while only reducing their efficiency by a small amount. Traditional photovoltaic cells achieve 20 per cent efficiency, while these new cells manage 12 per cent – substantially better than the 3 to 4 per cent achieved by other transparent cells. "At first thought, it was a crazy idea for all of us," says Kwanyong Seo, co-senior author on the paper published in the *Joule* journal.

The ultimate goal is to scale the technology up and limit the increasing demand that skyscrapers and tower blocks put on the power grid. "We want to replace windows," says Seo. "There are many things we have to overcome, such as the regulations by law. We need to have the mechanical stability and strength to replace current windows in buildings." On top of that, Seo and his colleagues will have to come up with a way to conceal the electrodes through which the harvested electricity will leave the solar cell.

> "THE ULTIMATE GOAL IS TO LIMIT THE DEMAND THAT SKYSCRAPERS PUT ON THE POWER GRID"



See-through photovoltaic cells (right) can still achieve decent efficiency

GETTY IMAGES, UNIST

SHOULD I BUY?

Oculus Quest

(now with hand-tracking)

£399, oculus.com

What is it?

The Quest is a VR headset that doesn't need a computer, a games console or a suite of external sensors to power it. It was first released last year, and now, thanks to a new update, it can track your hands and send them into the virtual world, ditching the need for clunky controllers.

So what?

Virtual reality is all about immersion: leap into the virtual world and leave your fleshy husk behind. Controllers just get in the way. So far, VR headsets have relied on handheld remotes that you have to learn to use while playing. For example, if you want to pick up a mug, you squeeze a trigger to grasp an object. Would Keanu put up with that?

How does it work?

The headset is pitted with an array of wide-angle cameras. It uses these to understand where your head and hands are in space and converts this into your point of view in the virtual world. With this new update, the headset's cameras are armed with sophisticated software that recognises the fingers and joints in your hand and reads their movement. This means that your hands only come into play when your headset can see them, which is more or less when you're looking at them.

What can you do with your hands?

So far the hand-tracking tech is still in pre-production testing mode. So it's all pretty raw. The most obvious demo to try out is *Elixir*, which lets you don some wizard robes and play with magic. Your movements are fluently translated between the physical and virtual worlds – you can play with bubbles leaping out of cauldron, or poke a dragon in the corner. In an instant, the whole experience is that much more natural, particularly for anyone who doesn't play a lot of video games. Playfully, you can turn your hands into octopus tentacles or Wolverine claws which, let's be honest, makes everything twice as fun. Going back to controllers to play other games once you've tried out the hand-tracking feels archaic.

What are the limits?

The wide-angle lenses detect your hands and fingers in the periphery of your vision, but when you lower your arms your hands disappear from the virtual realm. Right now, the interactions seem fairly discrete: the headset spots a gesture like pointing and delivers that instruction to the game. As the Quest goes through continual testing, it's clear they have the ingredients to make the way you interact with the virtual world more fluid.

Is it any good?

It's early days of course – technically the hand-tracking isn't even an official feature yet, it's simply a beta test – but letting go of the controllers and using the joysticks that nature gave you takes VR to a whole new level. While there are headsets that offer better graphics or more fidelity, Oculus is ultimately delivering a sense of immersion that's as good as it gets, and at a much cheaper price than most headsets. I'm certainly excited to see where it goes from here.

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↘ Jaguar's eTROPHY race sees drivers race I-PACE cars as the warm-up event for Formula E

Jaguar I-PACE boosts range by 20 kilometres

Motorsport teaches British manufacturer Jaguar how to get more miles out of its battery

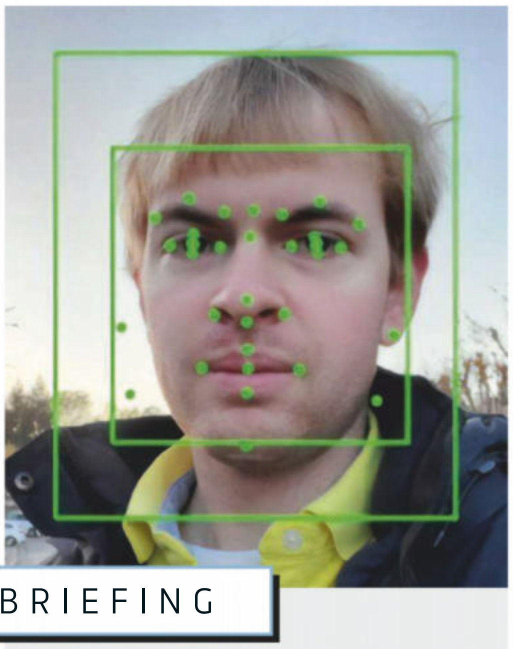
Jaguar is promising to add 20 kilometres (12 miles) of range to its I-PACE all-electric cars through a free software update. This extra performance has been eked out of the car, thanks to learnings from Jaguar's I-PACE eTROPHY race that supports Formula E motorsport. The new program will increase the I-PACE's stated range of 470 kilometres (292 miles) by 4 per cent.

"The Jaguar I-PACE eTROPHY has generated a huge amount of data for us to analyse, and those marginal gains, derived from competition on the track, are now being applied to customers' cars," says Stephen Boulter, I-PACE vehicle engineering manager.

> "THE JAGUAR I-PACE eTROPHY HAS GENERATED A HUGE AMOUNT OF DATA FOR US TO ANALYSE"

The software update allows the battery to trickle down to a lower level of charge but still keeps the car running. It does this by increasing the car's efficiency in 'eco mode' by altering the torque that its two electric motors deliver to the wheels. It also opens and closes vents around the radiator to improve the car's aerodynamics. Plus, more energy is harvested through the car's regenerative braking system as a result of the update.

I-PACE owners will need to take their cars to a Jaguar dealer to receive the free update. Once installed, however, the new software will enable the vehicles to receive future updates remotely.



BRIEFING

EMOTION RECOGNITION TECHNOLOGY

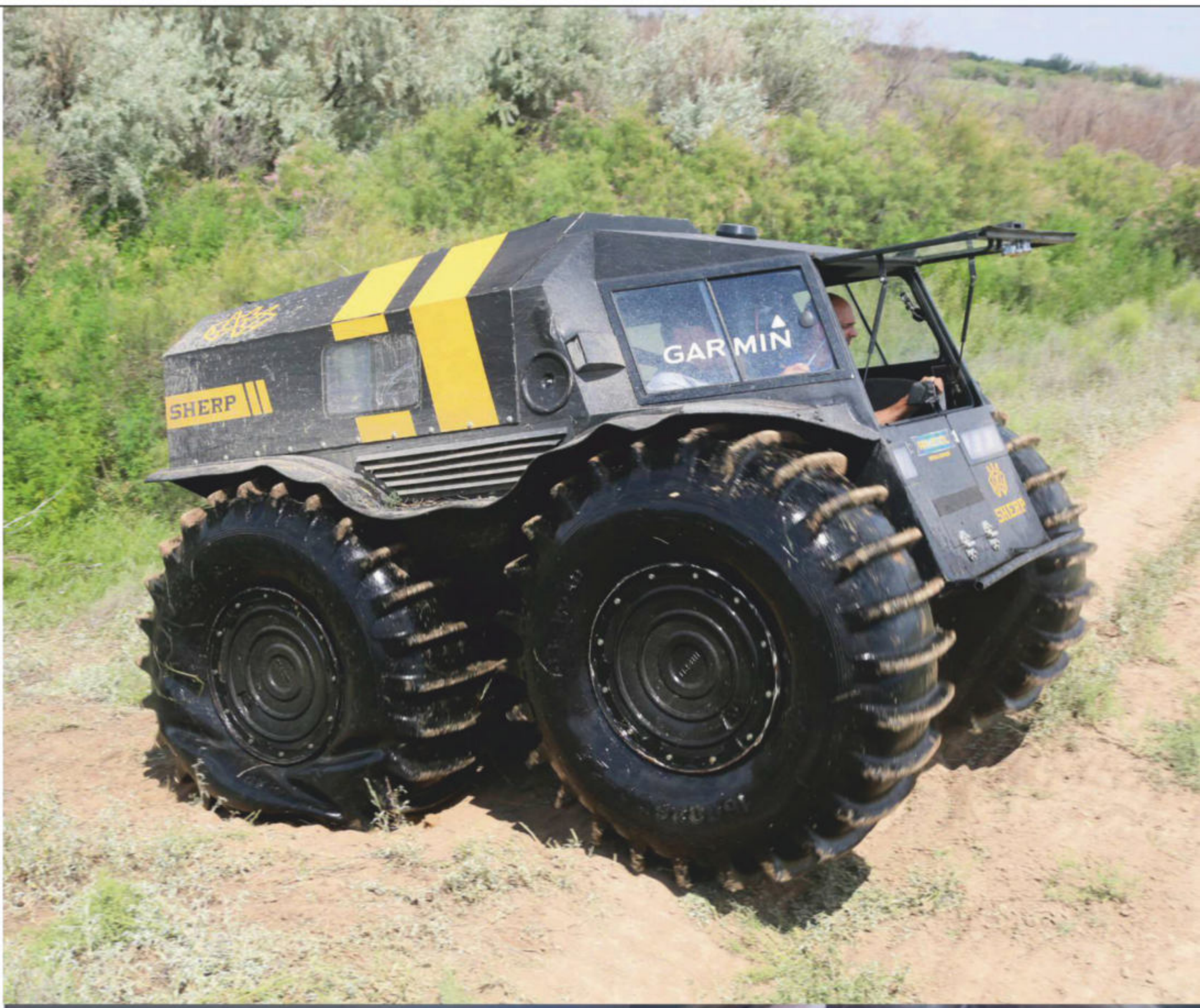
Some are calling for regulation. AI Now, a research institute based at New York University, has said that artificial intelligence tech that claims to recognise emotional states is "built on shaky ground". In the institute's annual report, which examines risks of AI proliferation, it suggested legal restrictions need to be put in place to prevent AI from being used in decisions that could affect lives.

It's a booming business. The industry could already be worth as much as $20bn (£15.3bn).

The tech is out in the real-world. Chinese schools have trialled the tech to monitor student attention, companies have used it to assess potential employees, and doctors have used it to measure patient pain. The report highlights a forensics company used by the FBI and Interpol who have added 'emotion detection' to its video analysis software as a means of identifying potential terrorists from drone footage.

The systems can be biased. The report highlighted a study which fed 400 NBA player photos into two emotion-recognition programs. Both systems gave black players more negative emotional scores on average, no matter how much they smiled.

Ideas we like...

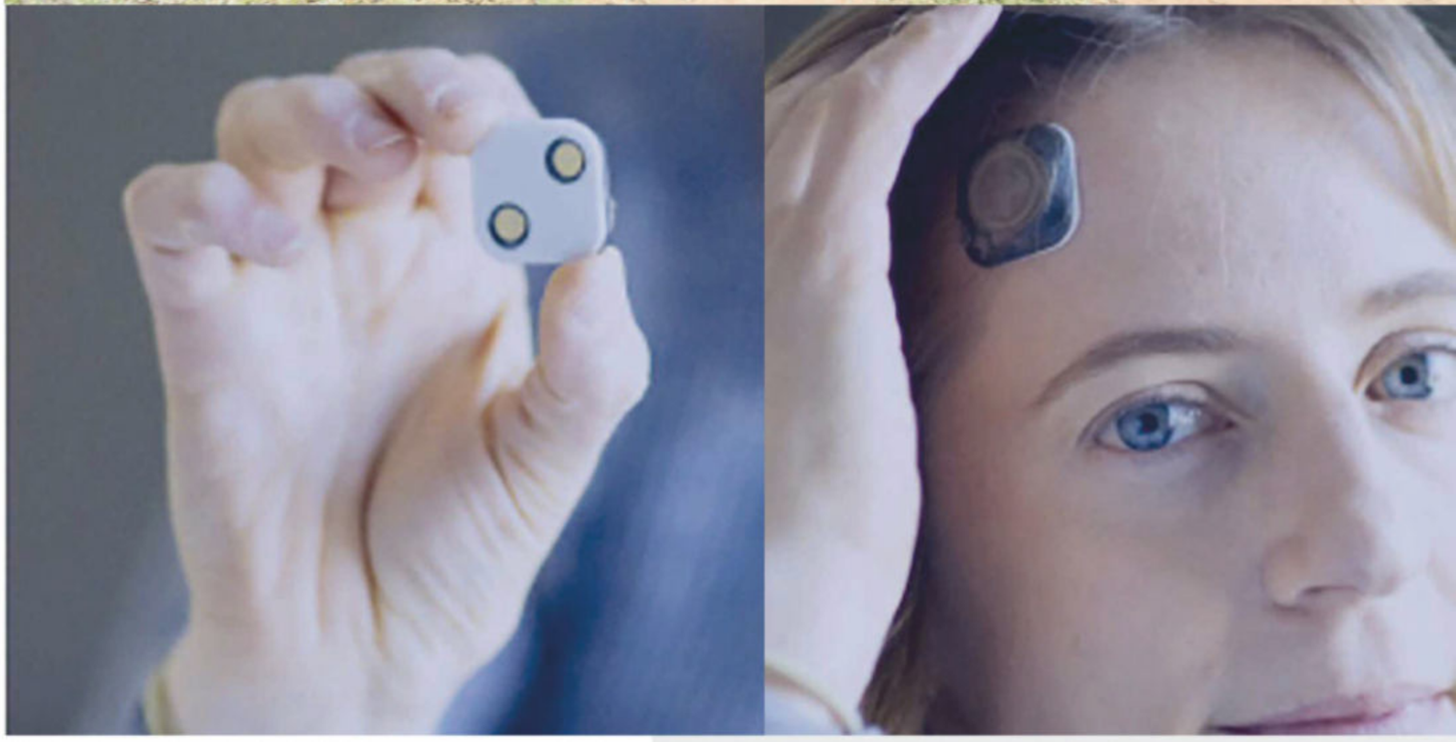


1.

A real-life Tonka Truck

When the world crumbles into a *Mad Max*-esque wasteland, this will be our weapon of choice. The Sherp promises to go anywhere and looks like it can; its high ground clearance and low-pressure tyres mean it can clamber up rockfaces and wade through rivers. And just like a toy truck, it comes with a range of trailers, including a medical module and an 'Ark' for living out in the wilderness. All we need to do now is figure out how to afford one.

Sherp ATV $119,000 (£89,000 approx), sherpatv.com



← 2.

Motorised surfboards

Let's be honest, if most of us actually got a chance to ride a motorised surfboard, we'd probably spend more time off it than on it. That doesn't make us want a new battery-powered board from Awake any less though. It can hit 56km/h (35mph) or 30 knots in four seconds flat, and will run for up to 40 minutes (less in 'extreme' mode). Who needs waves anyway?

Awake RÄVIK, €18,900 (£15,772 approx), awakeboards.com

↑ 3.

Wearable that predicts seizures

This little device is actually an EEG (electroencephalogram) monitor that reads your brain waves. The data is collected and sent to a machine learning system that tries to spot the signals that precede an epileptic attack and uses them to give people with epilepsy an hourly forecast. It's currently awaiting FDA approval, but Epitel, the company behind it, hopes it'll go on sale soon.

Epitel Epilog, £TBC, epitel.com

4.
A shirt that keeps you cool

This shirt's fibres are interwoven with phase change material – a fabric used to line astronauts' spacesuits. It absorbs heat (cooling you in the process) and releases that heat when it gets colder – perfect for spacewalks and offices without air conditioning.

Apollo Dress Shirt, $125 (£93.40 approx), ministryofsupply.com

↓ 5.
A post-apocalyptic Raspberry Pi

Riffing off the tech used in William Gibson's *Neuromancer*, this custom Raspberry Pi build is meant for the end of the world. This 'cyber deck' – which the novel's protagonist used to "jack into the matrix" – is waterproof, shockproof, and lined with copper (to keep out electromagnetic pulses). The switches turn off each of the build's components to save power. If the idea appeals to you, then knowing how to set up your own Raspberry Pi would probably be a good start – especially if you're preparing for the end of days.

Off-Grid Cyberdeck, back7.co

← 6.
Modular electric mopeds

This Swedish e-bike is pricey, but we love the idea of a battery-powered moped that you can build to suit your needs. There are bolt-on racks for the front and rear, a 'quiver' for hauling luggage on one side and the option for a passenger seat. You can also upgrade the power unit to handle the extra load and add a generator-style battery pack to provide power at your destination.

Ösa+, €8,500 (£6,352 approx), ridecake.com

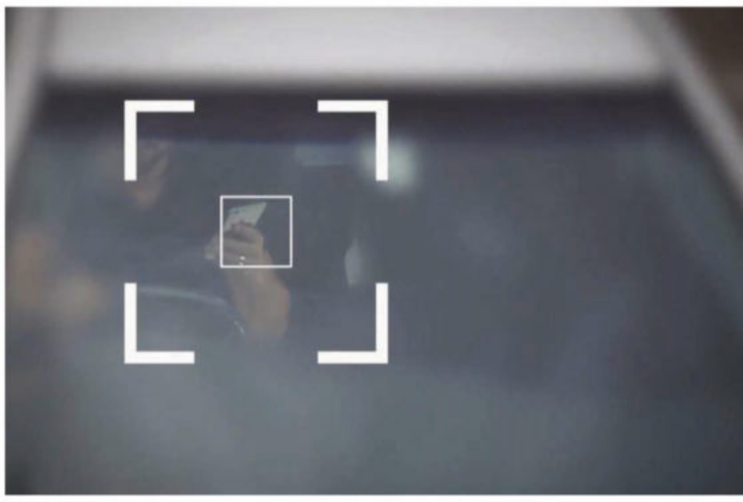
7.
Smartphone microscope

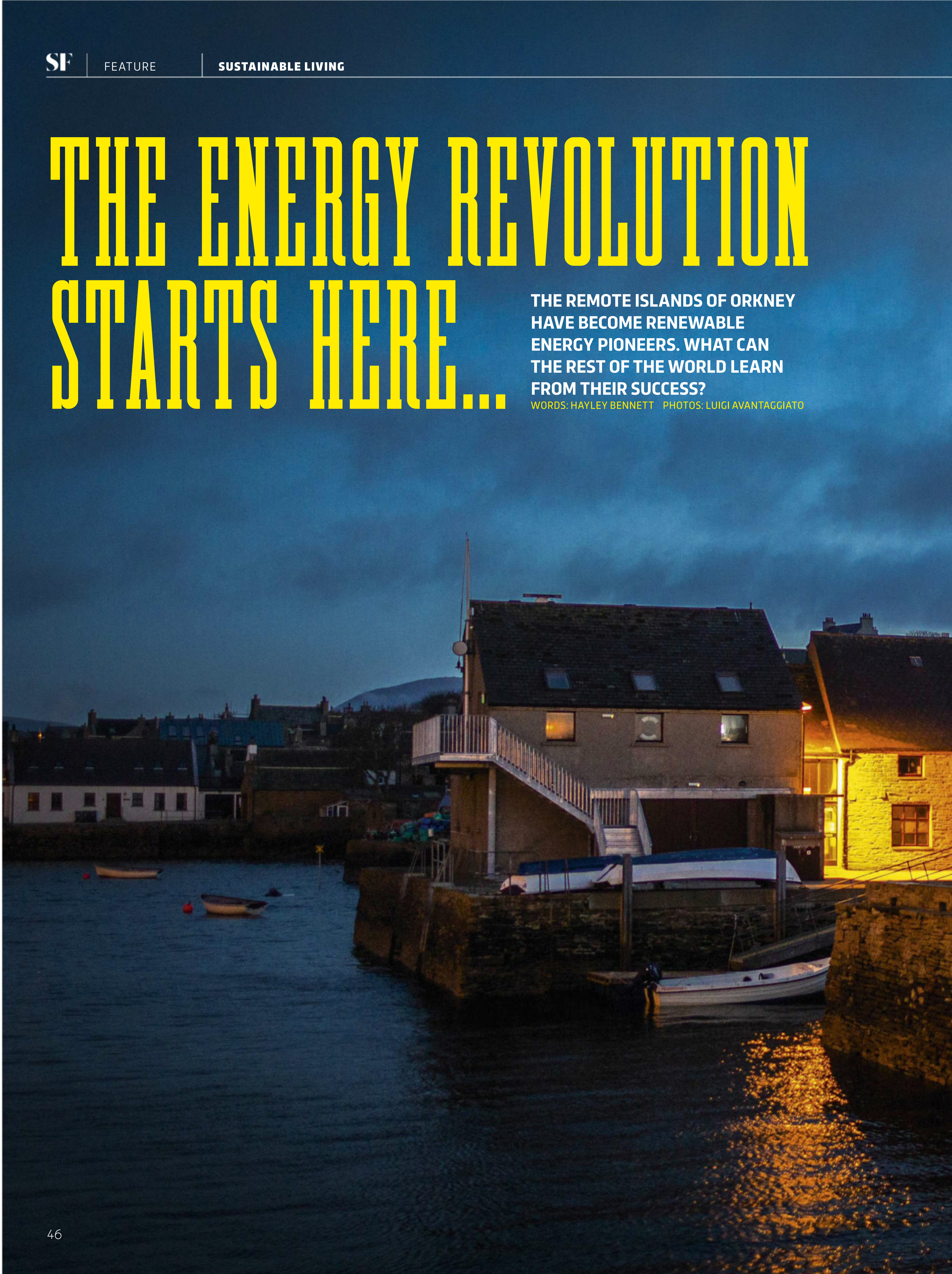
If you've ever peered through a microscope, you'll know how amazing it can be to see blood cells and microbes with your own eyes. Diple is an accessory kit that lets you experience that amazement by turning your smartphone into a microscope. The compact box contains a light source, a stage for samples and slides, and a metal plate with an optical system for magnification. Prepare to have your mind blown!

Diple, £TBC, diple.smartmicrooptics.com

↓ 8.
Cameras to catch texting drivers

In Australia, the traffic authority is introducing cameras that can spot when someone is using their phone while driving. The AI-powered system was trialled in New South Wales early in 2019, where it spotted some 100,000 drivers using their phone at the wheel. At first, anyone caught will receive a written warning – to make them aware of the new system – but repeat offenders will face a fine and/or penalty points added to their licence. Forty-five cameras will be installed around the state to catch anyone not paying attention to the road.





THE ENERGY REVOLUTION STARTS HERE...

THE REMOTE ISLANDS OF ORKNEY HAVE BECOME RENEWABLE ENERGY PIONEERS. WHAT CAN THE REST OF THE WORLD LEARN FROM THEIR SUCCESS?

WORDS: HAYLEY BENNETT PHOTOS: LUIGI AVANTAGGIATO

ENERGY AT THE EDGE

The 70 or so islands of Orkney may be isolated, sitting off the northernmost tip of the Scottish mainland, but they're at the heart of an energy revolution. The seaport town of Stromness (pictured), on the largest island ('Mainland'), draws visitors from Silicon Valley, Chile, Taiwan and everywhere in between, seeking to find out how Orkney is able to produce so much renewable energy – more than it can actually use. First stop is often the European Marine Energy Centre (EMEC), which is based in the town and is "the seed for all of the growth over the last 20 years," according to renewable energy researcher Dr David Woolf at Heriot-Watt University, Orkney. The juxtaposition between historical and contemporary is a common theme in Orkney: the harbourfront buildings shown here were formerly used in a herring fishing business but now include a modern art gallery, while across the islands wind turbines and electric vehicle charging points are as abundant as standing stones and the remains of Norse settlements.

TURNING THE TIDE ↓

The Fall of Warness tidal test site (pictured), located to the west of the island of Eday, offers seven grid-connected berths for testing tidal energy generation devices. There are a further six berths for wave energy devices at a separate site off the western edge of Mainland. When the EMEC was established in 2003, it was with the aim of becoming a world leader in the development of wave and tidal energy; together, the two sites have hosted 32 different devices from 11 countries.

"Orkney is a place that's got extraordinary energy in its landscape and seascape," says Dr Laura Watts, Edinburgh University ethnographer and author of *Energy At The End Of The World*. Waves up to 18 metres high and tides rolling in as fast as four metres per second are what attract developers. In 2008, Irish company OpenHydro was the first to send tidal power to the UK National Grid. One of the turbines it tested is shown here, although it's no longer operating – OpenHydro was liquidated in 2018. Currently, Spanish tidal developer Magallanes is testing at the site.

WINDS OF CHANGE →

Orkney is plentiful in wind. In fact, wind energy in the UK has its origins here: an experimental wooden turbine installed at Costa Head on Mainland in 1951 was the first grid-connected device. While this wind turbine soon succumbed to the 200km/h gusts, it paved the way for Mainland's Burgar Hill wind farm (pictured), established in 1983. Today, the wind farm hosts six turbines, one of which, in 2015, became the first UK device to generate over 100 million kilowatt hours of electricity.

There are also hundreds of privately owned micro turbines dotted around the Orkneys. According to Woolf, the Orcadians are an entrepreneurial bunch who have helped drive the growth of wind and other energy technologies here, both at the individual and the community level. "It varies from a local farmer saying 'Well, I can do quite well just putting up a small wind turbine on my farm, and that's going to pay me', to people getting involved in the bigger projects, like the wind farms," he says.

TESLA
ELECTRIC VEHICLES

BIG HIT
Building Innovative Green Hydrogen Systems in Isolated Territories
EDAY
SHAPINSAY
KIRKWALL
HYDROGEN REFUELLING STATION
FUNDED BY
Innovate UK
PARTNERS
ITM POWER
GIACOMINI
CALVERA
GRIT SALT

ELECTRIC DREAMS ←

Bankburn House on the island of South Ronaldsay was once the haunt of sea captains; now, it's a bed and breakfast equipped with solar panels, a wind turbine and a Tesla 'Destination' charging point for guests driving electric cars. According to owner Mick Fraser (pictured), when this Tesla charging point was installed, it was the northernmost in the UK. There's now a Tesla point 20 kilometres further north, at a gin distillery on Mainland.

Across Orkney, there are currently 28 electric vehicle charging points – more than there are petrol stations. The majority of these are operated by the council. However, with just 168 all-electric or plug-in hybrid vehicles registered at the last count in 2017, that might seem too many. That said, electric vehicles still make up a higher proportion (1.4 per cent) of vehicles than in any other Scottish council, and there are predicted to be 1,000 on Orcadian roads by 2023.

STORAGE SOLUTIONS ↑

This hydrogen refuelling station, located in Kirkwall, Orkney's largest town, supplies the council's five hydrogen fuel cell vans. The hydrogen is produced by electrolysers on the islands of Eday and Shapinsay, which use electricity from tidal and wind sources to split water into hydrogen and oxygen. The hydrogen can then be compressed, stored, transported and burnt to generate electricity at a later date.

This is especially useful for Orkney, because the islands currently generate around 120 per cent of their energy needs, and much of this excess is wasted. "Most of the time there's an energy surplus," says Woolf, "but there's not enough storage yet that we can totally cut ourselves off from the Scottish mainland." During still conditions, for example, Orkney has to pipe in some fossil fuel-derived electricity from the mainland. Developing storage options for energy should help to make the islands more self-sufficient.

COMMUNITY ASSETS

What can other places learn from Orkney's success? First, it makes clever use of its natural resources. The geography of Orkney determines the kinds of energy that are available; other places in the UK might need to rely more on solar energy, for example, or biomass. But perhaps more important is how communities – like Stromness, pictured here – can become the driving force of an energy revolution. According to Watts, it's not just about installing the relevant technologies, but about building relationships between the technology and the people who live there. "That work of maintaining a community is something that is ongoing in Orkney, and a lot of people are invested in it," she says.

Meanwhile, next-gen energy technology continues to emerge from the islands. A new EMEC-led project called ReFLEX aims to create a 'virtual energy system' that brings together the transport, heat and renewable electricity networks, which will allow energy to be more efficiently stored for when it's needed. The plan is to roll it out elsewhere in the UK and internationally. **SF**

by **HAYLEY BENNETT**
(@gingerbreadlady)
Hayley is a science writer based in Bristol.

SUPERCHARGE YOUR WILLPOWER

by ANDY RIDGWAY

New Year, new you… if only it was that simple. But it turns out scientists are discovering there are some mind tricks that can take your powers of self-control to the next level…

We've all done it. After a few days of successfully exercising self-restraint, the stresses of work, daily life and the New Year get the better of us. Our willpower cracks and the chocolate cupboard gets raided. Those plans to turn a daily trip to the gym into a habit get kicked into touch and we revert to sticking on a boxset and bidding farewell to the outside world.

Psychologists have coined a term for this all-too-common phenomenon: willpower depletion. It's the idea that the more we put our willpower under strain, whether it's through working hard or trying to stick to an exercise plan, the more it gets drained. And the more it gets drained, the less self-control we have to resist other temptations, such as junk food, binge-watching a boxset or spending money on things we don't need. Willpower depletion has been the conventional wisdom for decades.

But the more researchers are learning about it, the more they're finding that rather than being a finite commodity that gets depleted as we use it, the extent of our willpower is actually something that we can control.

What happens to our willpower or self-control really matters. "Self-control is a huge predictor of success or failure in life," says Prof Roy Baumeister at the University of Queensland in Australia. "People with better self-control are more popular, they do better at school and work, they are less likely to be arrested or divorced and they live longer."

A TEST OF WILLS

Baumeister is one of the main proponents of willpower depletion – an idea that can be traced back to Sigmund Freud in the 1920s. Over the past two decades, psychologists like Baumeister have dreamed up all kinds of creative ways to put volunteers' willpowers to the test in their labs to see if they do get depleted.

In the first study of its kind in 1996, Baumeister and his team placed a pile of chocolate chip cookies and a bowl of radishes in front of psychology students. Some were allowed to tuck into the cookies; others were told they had to resist the temptation and only eat the radishes. To crank up the strain on the radish eaters' willpower, they 'augmented' the cookies (to use the researchers' term) with a few chocolate sweets. The team even went to the trouble of baking the cookies in a little oven in the lab so it was filled with the aroma of freshly baked cookies.

All the students were then asked to trace a geometric shape using a pencil, without retracing any lines or lifting the pencil from the paper. ➧

ILLUSTRATION: MAGIC TORCH

▶ Unbeknown to them, it was an impossible task. What they were being tested on, was how long they stuck at it – in other words, how much willpower they had left. On average, the cookie eaters stuck with it for an impressive 18 minutes. Whereas the radish eaters, their willpower drained from resisting the temptation of the cookies, only lasted an average of eight minutes.

But more recently some psychologists have questioned whether our willpower does actually get depleted as we use it – or at least whether it gets depleted to the extent that the experiments that followed Baumeister's 1996 study suggested. In one huge study, conducted by psychologist Prof Martin Hagger, now at the University of California, Merced, 23 labs around the world carried out willpower depletion experiments in which volunteers completed tasks on a computer. The study found the willpower depletion effect to be small. In fact, in many instances it was so small that statistical analysis couldn't rule out the possibility that there was no depletion at all.

THE LAB VS THE REAL WORLD

Baumeister stands by willpower depletion and the experiments that have been done. "There are something like 600 significant findings in the research literature," he says. For his part, Hagger says willpower depletion is difficult to study in the lab – partly because it's so tricky to put willpowers under strain there. He says the best way to test for willpower depletion is to take the research out of the lab and into the real world. "What's needed are field-based studies where you catch people in a depleted state – and that's easier said than done."

Nevertheless, there have been *some* field-based studies and these have provided some evidence that our willpower does get depleted when it's put under strain. In one study carried out by Prof Mark Muraven, a psychologist at the University at Albany in the US, volunteers recorded how busy they had been at work and how stressed they had been in an electronic diary. When they were busier and more stressed, their alcohol intake shot up. "When a situation places considerable demands on your self-control, it has the potential to impair your ability to inhibit your impulses," says Hagger, who was not involved in the research.

But even if our willpower does have a tendency to get drained when it's under strain, there are promising areas of research that show that we can still exert control over it – supercharge it, even.

One of these promising research areas is investigating the possibility of training our willpower by giving it a small workout. The idea is that, similar to the way physical training works on our muscles, if we regularly put our willpower under small amounts of strain, it may be depleted in the short term but it will get stronger in the long term.

There's good evidence that this approach works. Prof Malte Friese at Saarland University in Germany worked with other psychologists to pool the results of 33 studies of willpower training involving 2,600 people to see if any trends emerged, in what's known as a meta-analysis. Collectively, these studies showed that even small, regular tests of willpower can give your self-control a lift. It may only be a small lift, but it's real.

The good news is that these willpower workouts don't have to be especially taxing to have an effect. In one of the studies in the meta-analysis, Swiss ▶

> "STUDIES SHOW THAT REGULAR TESTS OF WILLPOWER CAN GIVE YOUR SELF-CONTROL A LIFT"

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5 HACKS TO SUPERCHARGE YOUR WILLPOWER

Don't throw your sweets out

Now the New Year has arrived, it might seem like a good idea to throw out any sweets left over from Christmas to avoid the temptation. Well, don't. In one experiment, researchers at Catholic University of Leuven in Belgium put temptation in the way of student volunteers in the form of a bowl of Quality Street they were not allowed to eat. When they later had M&Ms placed in front of them, they ate fewer than the students who hadn't had the Quality Street temptation. Learning to resist temptation can have a powerful effect.

Swill a sugary drink

Having a quick hit of glucose by drinking a sugary drink can boost your willpower, several studies appear to show. Weirdly, you don't even need to drink the sugary stuff to get the benefit. Research carried out by psychologist Prof Martin Hagger while he was at Curtin University in Australia, showed that when volunteers just swilled a sugary drink around their mouths and spat it out, it still increased their willpower for tasks such as squeezing a hand grip or completing difficult brain teasers.

Avoid multiple resolutions

If exerting our willpower can diminish it for a while, it makes no sense taking on too many New Year's resolutions at once. While studies have shown resolving to diet and exercise can work if their collective goal is to reduce weight, tackling different goals simultaneously, such as losing weight, swearing less and tidying up more, could present too much of a willpower strain. "What I advise is to do them in sequence," says Prof Roy Baumeister at the University of Queensland in Australia.

Control your environment

Certain behaviours, such as eating too much or drinking too much alcohol, are sometimes prompted by cues in our environment. It could be that sitting down and watching TV alone prompts us to eat three packets of crisps in a row. Or a pub quiz night prompts us to drink excessively. "One strategy is to recognise the cues and try to structure the environment, so the cues don't arise or you have some sort of alternative," says Prof Martin Hagger at University of California, Merced.

Use mindfulness and meditation

An experiment carried out by Swiss researchers asked volunteers to watch disgusting YouTube videos showing things like someone having a spot squeezed on their back. But, to put their willpower under strain, they were banned from showing any response, such as grimacing. They were then tasked with crossing out apostrophes in strings of letters. Those who had practised mindfulness meditation between the two tasks, such as focusing on their breathing, performed better in the second test than those who hadn't.

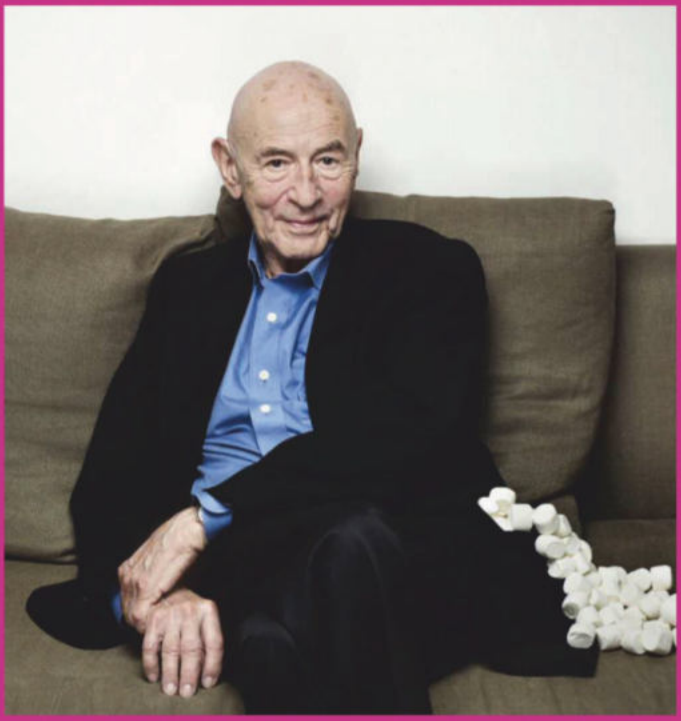
THE TROUBLE WITH MARSHMALLOWS AND WILLPOWER

The most famous willpower experiment ever conducted is the 'marshmallow test'. Developed in the 1960s by Stanford University psychologist Prof Walter Mischel (below), children aged three to five were left alone with a marshmallow and told they could eat it immediately but if they could resist eating the marshmallow for 15 minutes, they'd be rewarded with a second one.

When Mischel and his fellow researchers followed up with the same children in the 1990s, they found that those who had managed to hold out for the second marshmallow were doing much better, getting higher test scores and having lower BMIs.

But research published in 2018 tells a different story. Dr Tyler Watts at New York University along with Prof Greg Duncan and Haonan Quan at University of California, Irvine, staged a similar experiment. Only this time, the children were chosen to be representative of the general population in terms of their parents' educations and other characteristics (the children in the original marshmallow test studies came from a Stanford University campus pre-school).

In the 2018 paper, they found that the children who were able to hold out for the larger marshmallow reward still did better, but to a much smaller degree than the original research showed. Not only that, but once factors such as their family background and parents' educations were taken into account, the effect was even smaller. Intriguingly, the researchers say that how long the children were able to delay eating the first marshmallow was strongly correlated to measures of their intelligence. So to a large degree, the marshmallow test may actually be testing how bright the children are rather than their level of self-control.



students were asked to repeatedly perform an unrewarding menial task to train their willpower, squeezing a handgrip exerciser for as long as possible twice a day over two weeks. It seemed to be enough to boost their average marks in exams. In another study, volunteers had to use their non-dominant hand for a set period of time. Exactly how these actions improve your willpower isn't clear – one suggestion is that these willpower workouts work by increasing our perception of how much self-control we have.

A similar mechanism may well be at work in another area of research being conducted by a group of psychologists in the US and China – using rituals. Rituals are pre-defined sequences of actions we carry out that are repeated. And while some of the rituals being tested may seem bizarre, they seem to work wonders for our self-control.

In one experiment, women from a college gym in the US were asked to perform a ritual before they ate their food. They had to cut the food on their plate into pieces, rearrange them so the pieces were symmetrical then press their fork on the top of their food three times. Those who performed the ritual ate 1,424 calories, on average, each day. Another group of volunteers from the gym who were encouraged to just think about the amount of food they ate each day during the research consumed 1,648 calories on average.

"The rigidity and the repetitiveness of the ritual behaviours really seem to be signalling to the person, 'hey, I'm someone who has willpower,'" says Dr Juliana Schroeder at the University of California, Berkeley, who was involved in the ritual research. "It's a self-perception mechanism."

Since repeated sets of actions that restrict food consumption can be associated with eating disorders, the researchers add that caution is needed but if undertaken carefully, they say that rituals can promote wellbeing.

WILL YOUR WAY TO WILLPOWER

Our perception of our willpower is a thread that runs through much of the recent research into how our self-control might be given a lift. But while most of the research has been carried out in Western countries, some has taken place elsewhere and it's provided an intriguing insight into the inner workings of willpower.

In one study carried out by Dr Krishna Savani at Nanyang Technological University in Singapore and Prof Veronika Job at the University of Zurich, a group of undergraduate students in Bangalore, India, were given huge, difficult mazes to solve to stretch their willpower. Others were given tiny, simple mazes. They were also tasked with pressing buttons when they saw the colours red, blue, green and yellow appear on their screens, and tested on how accurate they were. To make the test harder, the colours were spelled out but sometimes the word that appeared didn't match the colour being displayed.

It was assumed that when willpower depletion took hold, the students given the huge, difficult mazes would perform worse in the colour task than those given the tiny, simple mazes. But that isn't what happened. In fact, the exact opposite happened: those who had their willpowers put under strain by the huge mazes were actually more accurate in the second test.

> "IF WE BELIEVE THAT USING OUR WILLPOWER IS ENERGISING RATHER THAN DRAINING, IT IS"

The effect, referred to as reverse ego depletion, may be down to culture, says Savani. "Many Indian practices, such as meditation and concentration, emphasise the idea that people can exert willpower over extended periods and that it has a positive rather than a negative effect," he says. In other words, our beliefs about willpower influences our perception of what happens when we exercise it. If we believe that using our willpower is energising rather than draining, it is. Reverse ego depletion has been found in willpower studies in other non-Western countries too, such as China.

The good news is that our beliefs about willpower can be easily swayed. In one of Job and Savani's experiments they gave a group of Indian and American volunteers what was said to be a scientific article stating that using willpower strengthens it. Another group received a different article saying using willpower diminishes it. Those from both India and the US who read the article saying using willpower is strengthened performed better in a test after they had their willpowers put under strain. "This research shows that our beliefs about willpower are a self-fulfilling prophecy," says Savani. "So people can be informed about this research and hopefully it will lead them to change their beliefs about willpower."

If he's right, it means that simply by reading this article you now have more willpower than you did before. SF

by **ANDY RIDGWAY** *(@AndyRidgway1)*
Andy is a freelance science writer based in Bristol.

DISCOVER MORE

BBC WORLD SERVICE *Listen to Claudia Hammond discuss using willpower to motivate yourself in this episode of* Health Check
bit.ly/willpower-check

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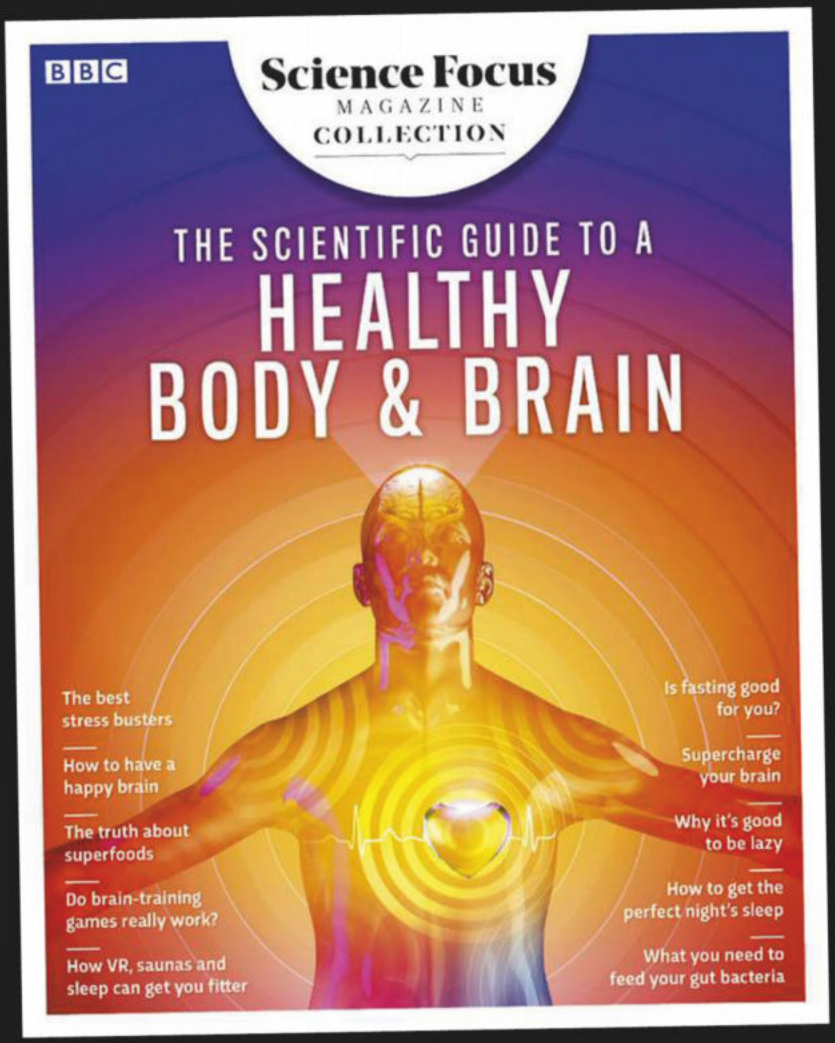
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COMMENT

THE END OF AN ERA?

Group dynamics – the study of how people interact – is fading into oblivion. And it's all because the research can't be carried out online

Every year, I make a list of New Year's Resolutions. I've kept each year's list and recently had a look at how well I'd done over time in my attempts to change my behaviour. Generally, it seems I'm over ambitious, particularly in the number of academic articles I say I'll write and submit. I recently discovered that this is a problem I share with many social psychologists. A delightful article published in October 2018 called *The MTurkification Of Social And Personality Psychology* describes the ebb and flow of popularity of certain fields of study within my area of social psychology. In the paper, Dr Craig Anderson and his team looked at group dynamics – how people interact within a group – and wondered why this formerly popular area of research was no longer part of the conversation. They landed on two reasons.

First, reward. Let's consider a job. You win a job when you impress an interviewer. But for the last 20 or so years, you've had to be a particular kind of impressive – one that's different from the kind of impressive that was rewarded for the first 100 or so years of the field. Long ago, you could get a great job even if you only published one article every couple of years. The rest of your time was spent doing research. Nowadays, you have to publish five articles per year to even be considered for a job. But the researchers argued that group dynamic studies are psychologist-heavy: lots of slow studies, extended research periods, on-site involvement, heavy investment. There's no time to write. Therefore, no reward.

> **"What else is being excluded because of these kinds of small yet systematic changes in our society?"**

The second reason is that more and more psychologists are going online to find their participants, and this is affecting the kind of research they can do. I remember when I was doing my own research that the virtual environment was a brave new world for group dynamics researchers like me: millions of people from everywhere milling around together being, well, dynamic. What a Petri dish! Quick! To the research stations! But once you build your study, how do you get the people to come? In the past, researchers recruited students in Psychology 101 classes. Now, the easiest way to get participants is to exploit the ready and willing gathering of people who will do something for a tiny amount of cash: the Amazon Mechanical Turk.

According to the MTurkification study, more than one-third of participants in published research studies are recruited from Mechanical Turk – effectively crowding out the pool of college student participants. But the thing is, you can't test for group dynamics using Mechanical Turk. You can only ask people to do simple surveys or respond to simple tasks. In other words, you cannot do group dynamics research this way.

And so, it's not that people aren't interested in learning about the stuff that group dynamics researchers study; it's that the requirements of participation are excluding the group dynamics studies. What else is being excluded because of these kinds of small yet systematic changes in our society? Let's make it a New Year's Resolution to find out. **SF**

ALEKS KROTOSKI
Aleks is a social psychologist, broadcaster and journalist. She presents *Digital Human*.

PORTRAIT: KATE COPELAND ILLUSTRATION: JASON RAISH

COMMENT

LIFE IN THE FAST LANE

Have breakfast a little later, and dinner a little earlier, and reap the health benefits

One of the biggest health trends in 2019 was 'intermittent fasting'. There is every sign that interest will continue in 2020, and I like to think I am partly responsible.

Seven years ago I wrote a book called *The Fast Diet*, all about the benefits of intermittent fasting. The book featured a new approach to dieting called the 5:2, which involves cutting your calories to around 600 calories for two days a week, and eating healthily for five days. In the book, I also wrote about Time Restricted Eating (TRE). The idea here is that you simply extend your normal overnight fast. If you stop eating at 8pm and don't start eating again until 10am, that is a 14-hour fast. That way you get some of the benefits of intermittent fasting without worrying about calorie counting.

The original TRE studies were in rats, and it took a while for human studies to get going. In fact, the BBC series *Trust Me, I'm A Doctor* was one of the first to do a human TRE study with Dr Jonathan Johnston of the University of Surrey. For this study, which was later published in 2018 in the *Journal Of Nutritional Science*, we recruited 16 healthy volunteers and measured their body fat, blood sugar and cholesterol levels. They were then randomly assigned to TRE or a control group.

The TRE people were asked to stick to their normal diet but to move their breakfast 90 minutes later, and their dinner time 90 minutes earlier. This meant that for three extra hours each day they were without food (fasting). Everyone kept a food and sleep diary to ensure that they were eating the same amount as normal.

> "The group who had eaten breakfast later and dinner earlier had, on average, lost 1.6kg of body fat"

Ten weeks later, we repeated the tests. We found that the group who had eaten breakfast later and dinner earlier had, on average, each lost around 1.6kg of body fat. They had also seen bigger falls in blood sugar and cholesterol than the control group. A more recent study, published in the journal *Cell Metabolism* on 5 December 2019, did something similar. This time, researchers took 19 overweight volunteers with metabolic syndrome (raised blood sugar, blood pressure and cholesterol) and asked them to eat within a 10-hour window. Although the recruits were asked to eat as much as normal, many of them said they were eating less, due to the shorter eating window.

As with the *Trust Me* study, the participants found that extending their overnight fast led to a significant reduction in body fat, blood pressure and total cholesterol. Blood sugar and insulin levels also improved.

Metabolic syndrome is a risk factor for developing type 2 diabetes. Therefore if we can prevent people with prediabetes from developing diabetes by adapting their fasting window, then it could save the NHS billions of pounds a year. I look forward to seeing more intermittent fasting studies in 2020. SF

MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor.* The new series is out in January.

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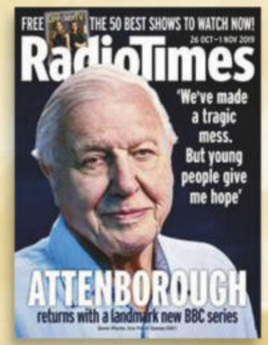
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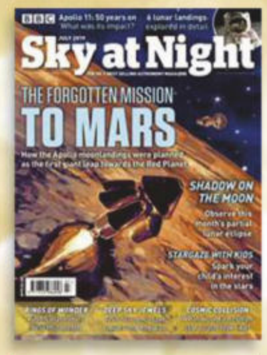
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GREEN TEMPLETON COLLEGE/UNIVERSITY OF OXFORD

INTERVIEW

BUILDING MEDICINE FROM NATURE'S BLUEPRINTS

Nanotechnology has the potential to revolutionise medicine – enabling us to target cancer cells, deliver drugs and fight antibiotic resistance, says biological physicist **SONIA CONTERA**. She speaks to **AMY BARRETT** about her work as one of the world's leading nanotech pioneers

WHAT IS NANOTECHNOLOGY?

Nanotechnology is the capacity to visualise, manipulate or fabricate matter at the nanometre scale. It can be many things, from fabricating a small nanoparticle to creating structures made of DNA as a building block. Or even, I would argue, creating new proteins and structures with new proteins, or creating devices to look at things at the nanoscale. Nanotechnology is a very broad term.

HOW SMALL IS 'NANO'?

If we go by the orders of magnitude, a nanometre is a thousand times smaller than a micron [which is 1,000 times smaller than a millimetre]. A normal optical microscope can't go down to the nanometre scale. A normal microscope can see a bacterium, for example, which is a micron in size.

The nano is the scale of biology, of our molecules. This is the scale that gave rise to life on Earth, so it's a very special scale. That's why material scientists are also interested in nanotechnology, because you can do things at that size that you can't do at any other size – it's important for medicine, for materials and, indeed, to understand life on Earth.

WHEN YOU SAY 'CREATING NEW PROTEINS', IS THAT PROTEINS THAT DON'T EXIST IN NATURE?

Correct. For the last 70 years or so, scientists have been interested in understanding the building blocks of life, which are proteins. We are made of collagen, for example, a tree-like protein, which is a nanometre in diameter. Collagen constitutes the scaffolding within the cells of our bodies, which gives us shape…

In the last decade, we've seen huge breakthroughs in our understanding of proteinal structure. People have been able to predict, using a computer, a proteinal structure without doing the experiment – just by knowing the protein's sequence.

This has led people to think about defining proteins that don't exist in nature. The protein is defined in a computer and then you create a DNA or an RNA code for it. You put the code inside a living cell, such as yeast, which you use as a living factory, and then nature produces your nanoscale materials.

This is a radical new way of doing science. Scientists are thinking of using these nanoscale materials as drugs, but also as building materials for the future, because the protein you design in the computer is defined with atomic precision. And you can define them to assemble into the structures you want.

Of course, it's still early days and only a limited amount of some proteins with the specific characteristics can be made this way. But it's a radical point. We're using biology to create our nanostructures; we're merging with the capacity of nature to build the materials. ▶

> “One of the nice things about nanotech is that it can actually make treatment cheaper. That’s something most of us think about when we do our research”

IS IT JUST PROTEINS THAT CAN BE USED TO MAKE NANOSTRUCTURES?

No, people use DNA: actually, the first biological material used to make nanostructures was DNA. DNA is made of four building blocks, like Lego, and these building blocks can stick to each other in very precise ways. So people thought you could use DNA to build any structure you wanted.

It took some time, but now you can build any shape you like with DNA. You can go to the computer, define your shape, order the pieces of DNA online, put them in the test tubes, heat them up, shake them around a bit and the structure you want will assemble.

The main challenge is that you build very small structures and it’s unclear how you connect them to make something useful. That is one of the challenges with these technologies right now. But, because it’s such multi-disciplinary area, people will immediately start thinking of applications for all different structures and mixing them with other structures that are already in nature.

HOW FAR ARE WE FROM BEING ABLE TO USE THIS TECHNOLOGY IN MEDICINE?

Well, I’m not sure we’re that far away. I think in our lifetime we will have some drugs based on proteins that do not exist in nature, or combinations of those with other drugs, or with DNA nanostructures. Perhaps not in 10 years, more like 20.

Actually, scientists are starting to make DNA structures that are specifically designed as part of a bigger structure. For example, so that they match a whole virus. It mimics what your body does when it’s trying to get rid of infections – our immune cells are sometimes able to explode themselves and the body uses the DNA that was inside the immune cell’s nucleus to trap bacteria and pathogens. We’re starting to learn these tricks that our bodies use. It’s a work in progress. Drug delivery – to find a specific place in the body that you want to target with the medicine – is a very complicated problem.

But we’ll learn more. We’ll have better mathematical models about the body, and how the body brings drugs to tumours or pockets of infection. I think the breakthroughs won’t come from a single field; it’s the convergence of fields on a specific problem that will bring the breakthroughs.

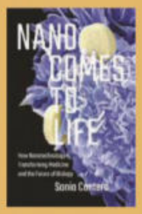
One of the most important things that nanotechnology has done is bring physicists and engineers to medical problems – by doing so we have much greater capacity to tackle the biggest medical or material challenges of our time. I don’t think we can solve those problems without the convergence of sciences.

IS NANOMEDICINE SOMETHING THAT EVERYONE WILL HAVE ACCESS TO? IS THERE A DANGER THAT NANOMEDICINE COULD BE RESERVED FOR JUST THE SUPER-RICH?

One of the nice things about nanotech is that it can actually make treatment cheaper. That’s something most of us think about when we do our research. You choose topics of research that actually improve the lives of people – as many people as possible.

One example would be detecting chemicals or diseases in your body. Right now, detecting tumours that you can’t touch or feel, such as pancreatic tumours, is very difficult. So, from the beginning of nanotech there has been a huge effort to create biosensors that will detect if you have a tumour or if you have diseases very quickly. This has been a bigger challenge than everybody anticipated… But the breakthroughs are starting to come. Two or three weeks ago, very quietly, a Japanese company, Toshiba, released a biosensor that is able to detect a lot of tumours with a single drop of blood, and quite cheaply. I think they were talking about £100 per test. If you could take one of these tests every two years to detect a tumour, it would definitely reduce the cost of healthcare. So, if there’s a will in the scientific and healthcare communities, we can use nanotechnologies to make the detection and treatment of diseases cheaper.

Of course, this is a complicated problem. These technologies are disruptive. They are disruptive of how we do medicine right now, especially in the West. We have a lot of big, medical conglomerates and it’s not necessarily good for them that we make things cheaper. So, I think, some of the main players in this field are South Korea, China and Japan, and they’ll change the way we do things.



SONIA CONTERA
(@soniacontera)
Sonia is an associate professor of biological physics at the University of Oxford. She studied physics in Madrid, where she learnt about the new tools being developed that would enable people to see atoms and nanomatter for the first time. She did her PhD in Japan, studying mainly nanotechnology and physics at the nanoscale. Since then she has worked across physics and biology, applying the building principles found in nature to engineer new materials. Her book, Nano Comes To Life *(£22, Princeton University Press), is out now.*

GREEN TEMPLETON COLLEGE/UNIVERSITY OF OXFORD

ABOVE
Dr Sonia Contera researches nanomaterials for use in medicine in her laboratory at the University of Oxford

HOW COULD A BLOOD TEST DETECT TUMOURS?

There are many ways in which people are trying to detect chemicals or molecules or proteins in the body. Usually you design a protein that will bind to an antibody and that would trigger a kind of signal that you can measure. [That signal] could be a change in optical or electrical properties. Then, ideally, you want to make the device to measure that signal cheaply and simply. I'm working with a group of Japanese scientists trying to develop an electrical device for detecting viruses.

When you have an infection, for example, it's important to know if the fever you have is caused by bacteria or a virus. For that, we need better tests. There are many people working on this and I think we're starting to see the first breakthroughs. After the first big hype about biosensing that we had in the early 2000s, work has been getting on and I think in the next 5-10 years, we'll see much better and much cheaper diagnostic tools in the clinic, hopefully.

IF WE COULD BETTER DETERMINE IF AN INFECTION IS CAUSED BY A BACTERIA OR A VIRUS, WOULD THAT HELP US ADDRESS THE PROBLEM OF ANTIBIOTIC RESISTANCE?

Of course. Because the problem we have right now is that when you're very ill, they don't give you antibiotics because it might be a virus, or it might not be. But if we can definitely tell you have a bacterial infection, and that you need antibiotics and you need to have the right antibiotics, we can be much more targeted.

WHEN YOU THINK ABOUT NANOMEDICINE, YOU ALWAYS IMAGINE SOMETHING LIKE THE SCI-FI FILM *INNERSPACE*, WHERE SCIENTISTS PUT SOMEONE IN WHAT AMOUNTS TO A MECHANICAL SUBMARINE, SHRINK THEM DOWN AND THEN THEY GET INJECTED INTO THE PATIENT'S BLOODSTREAM. THAT'S NOT REALLY THE NANOMEDICINE YOU'RE DESCRIBING, IS IT?

Yeah, that sort of vehicle can't be built. I don't think humans have the capacity to build nanomachines that can rotate or that can walk or that can bind to a virus just with atoms. We can't do it. What we are learning in biological physics is that the complexity that you need is in the nanomachines that run our bodies, that have been created through billions of years of evolution of life on Earth.

It's not just physics, it's not just chemistry. It's how the early organisms in Earth started to change the landscape of Earth so that more complex organisms could develop. All those billions of years of evolution has been defining our building blocks.

I don't think we can build proteins as clever as nature does, but we can learn how nature does it. And we can learn to work with nature to improve our technology.

We were just looking at the genes for a long time. Now we know that for every disease, there are thousands of genes involved. DNA is a much more wonderful, complicated machine that links physics and the history of life on Earth to the environment. We now know that the environment can do things to change our DNA.

We are re-encountering something I think we knew from the beginning of civilisation, which is that we emerge from nature. We are entangled with nature and the future of us as humans is entangled with the future of the planet.

This is a lesson that we're not only learning as a result of the environmental crisis, but it's also a lesson we're learning in the laboratories where we're trying to do medicine and the laboratories where we're trying to build new materials. We need to learn, from nature, how to create the next generation of technology. SF

DISCOVER MORE

ON THE PODCAST
Subscribe to the Science Focus Podcast *and listen to our full interview with Sonia in an upcoming episode.*
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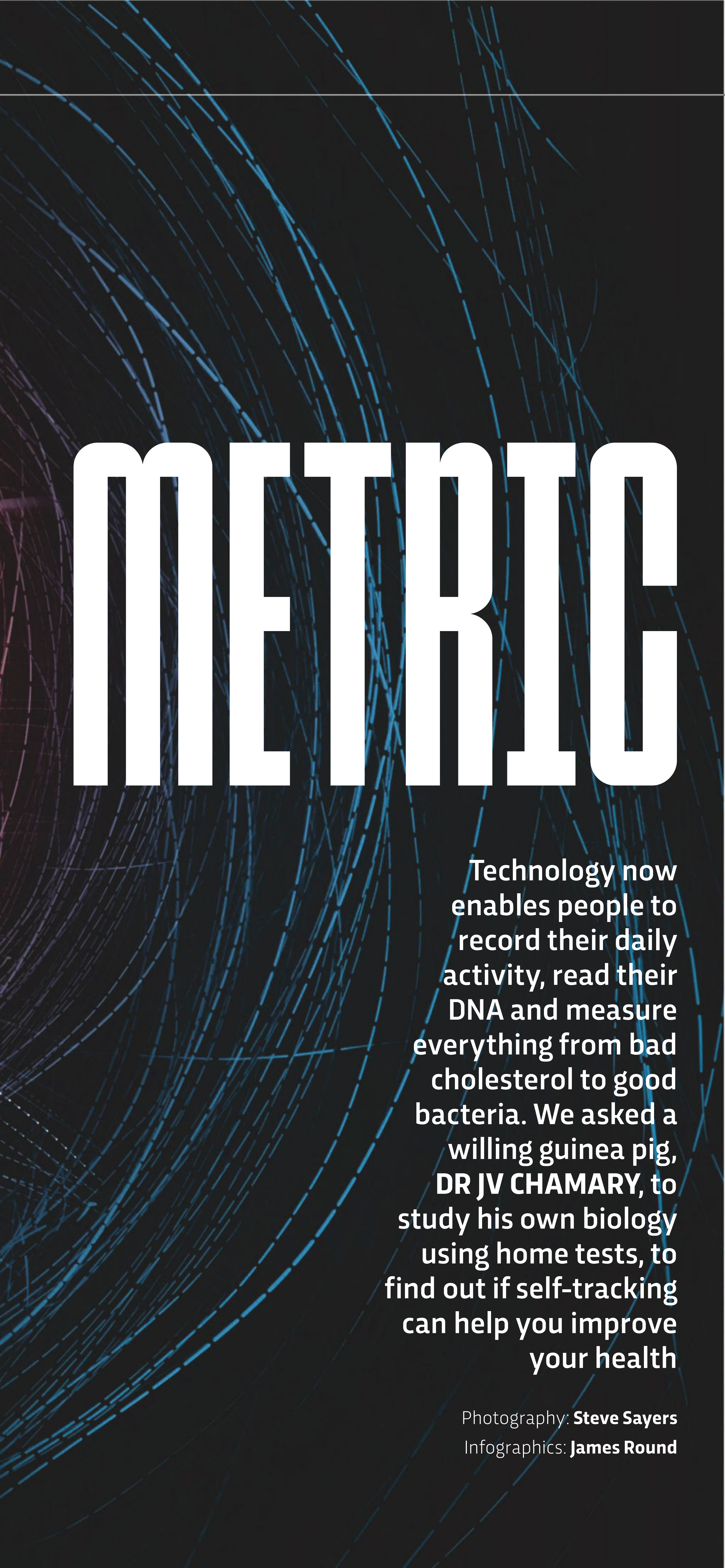


METRIC MAN

Technology now enables people to record their daily activity, read their DNA and measure everything from bad cholesterol to good bacteria. We asked a willing guinea pig, **DR JV CHAMARY**, to study his own biology using home tests, to find out if self-tracking can help you improve your health

Photography: **Steve Sayers**
Infographics: **James Round**

Over the last few months, I have been turning myself into a superhero. Not a very good one though, as the only person I can save is myself and my special powers are the ability to bleed, spit and defecate. But by collecting my bodily fluids to measure aspects of my biology – 'biometrics' – and tracking my activity, I have become 'Metric Man'.

Using technology to quantify your life, known as 'self-tracking' or 'quantified self', has become easy thanks to the availability of affordable wearable devices and direct-to-consumer tests. For example, the price of sequencing a whole human genome has dropped dramatically: in 2003 it cost scientists $3bn to read almost every letter in our DNA, but today a company will do it for just £150.

Dozens of companies are offering to analyse everything from epigenetics to gut microbes to help inform decisions on lifestyle changes that might improve your health. Are those firms selling personalised medicine, or snake oil? To answer that question, I'll share what I've learnt from six months of ▶

▶ self-tracking. First, a bit about the guinea pig. I'm almost 40, fit and relatively healthy. My diet contains too much junk food. I usually cycle 30 minutes per day, practice martial arts three to four times a week and go running with my dog twice a month. To track daily activity, I wore a Fitbit device almost 24 hours a day, only taking it off for karate classes (for safety) and charging. Tracking shouldn't completely take over your life, so I didn't log my food, water intake or body weight. Later, the calendar, messages and photos on my phone let me figure out what I was doing on a particular day and how that was reflected in my daily activity.

To assess what biometric tests can detect, I ran a little science experiment and sampled my bodily fluids on three dates over the six-month period (12 April, 18 June and 13 August 2019). The first and third collections were done in a typical week, with normal exercise and diet. But the second set was different: the tests were done the day after a brutal four-hour grading exam for a black belt in karate.

The exam was preceded by a month of intensive training and two weeks without alcohol. I controlled for as many variables as possible and my blood, saliva and stool samples were all collected within a one-hour window, which required prior planning and a cup of coffee. My hypothesis was that at least some results from the second set of tests would differ from the first and third measurements. ▶

1. DAILY ACTIVITY

Fitbit tracker / From £50 / Turnaround: 1 day

Activity trackers use an accelerometer to count your steps and determine the distance you've travelled by multiplying steps by your stride length. They also use an altimeter to measure the number of floors you've climbed. The amount of calories burned comes from an estimated 'basal metabolic rate' or BMR (how hard your metabolism works to maintain the body at rest, according to age, height and weight). Fitbit's smartphone app shows five default goals for physical activity: 10,000 steps, 10km distance, 10 floors and 30 active minutes (all semi-arbitrary targets not supported by science) plus a goal for calories burned based on BMR. Fitbit uses algorithms to estimate sleep via activity sensors or 'activigraphy'. In contrast, professional sleep researchers use multiple indicators – including rapid eye movement (REM) and brain waves via an electroencephalogram (EEG) – to get readings. "We define sleep as the EEG signature, the rhythmic firing of the neurons," says psychologist Dr Kelly Baron, who specialises in sleep medicine at the University of Utah. "If you're estimating it based on movement and heart rate, it's not as good."

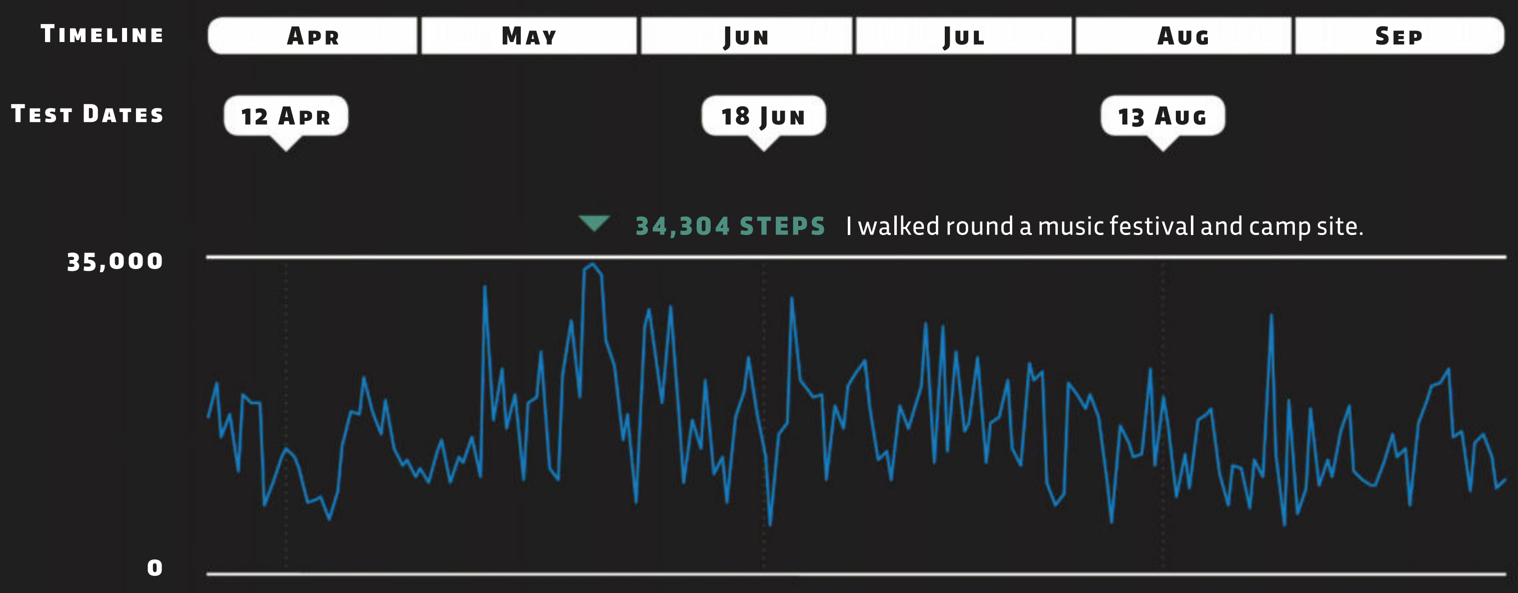
Fitbit recently added sleep stages (awake, REM, light and deep sleep), which isn't actionable data as you can't really force your brain to get more REM, only more sleep in total.

STEPS

Total 2,955,074

Mean 16,148

Goal 10,000



▼ **34,304 STEPS** I walked round a music festival and camp site.

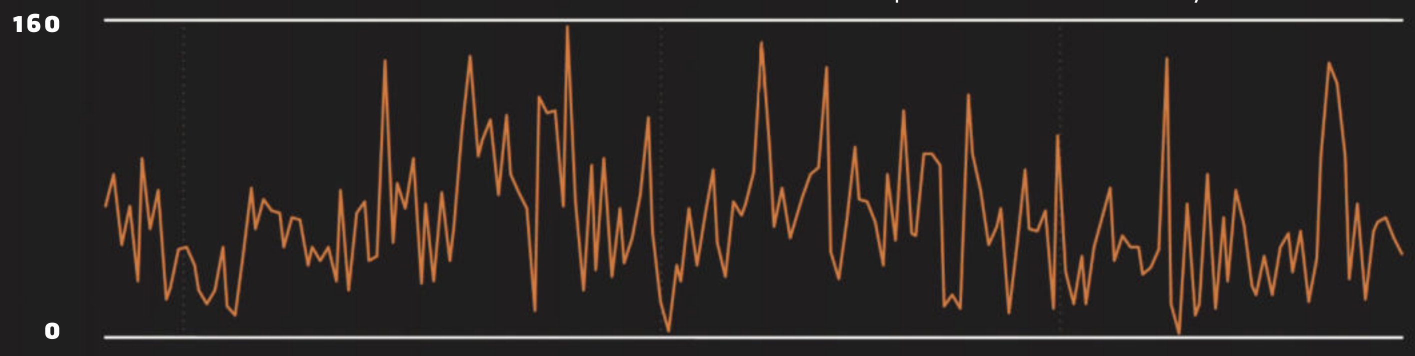
▲ **5,458 STEPS** I couldn't move for two days after my exam.

FLOORS

Total 10,740

Mean 59

Goal 10



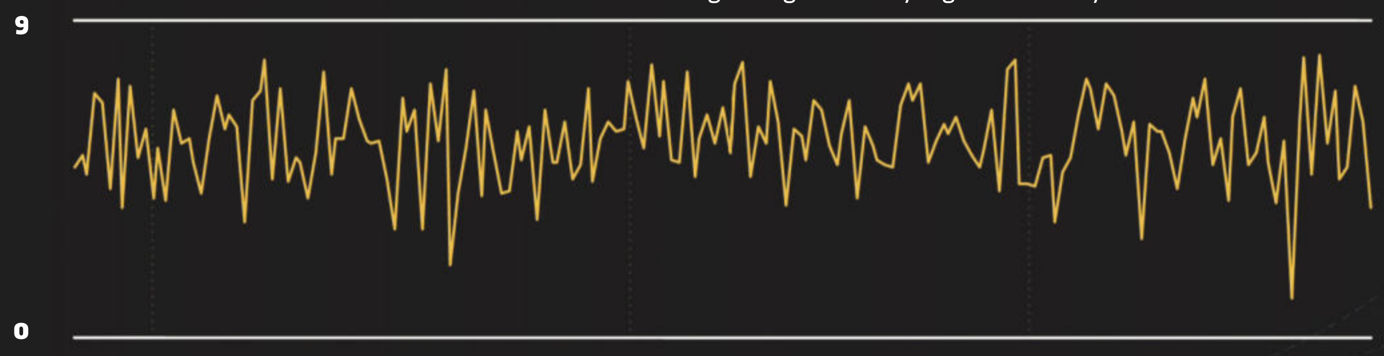
▼ **158 FLOORS** I did hill sprints for fitness before my exam.

I was visiting my aunt, who lives in a bungalow. **2 FLOORS** ▲

SLEEP

Total 1,027 HRS

Mean 5 HRS 27 MINS



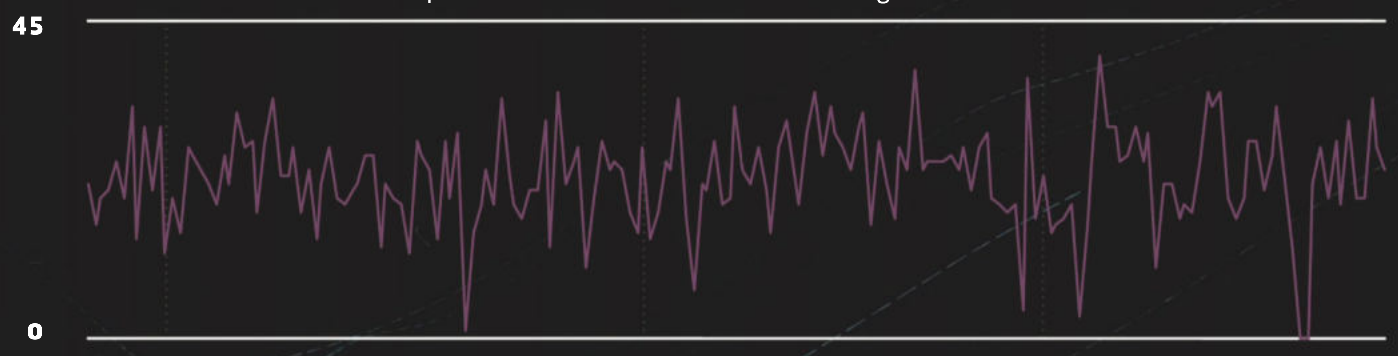
I managed to get an early night on holiday. **7.98 HOURS** ▼

Fitbit tracked poorly on a sleeper train. **1.15 HOURS** ▲

AWAKENINGS

Total 4,177

Mean 23



A persistent headache meant a restless night. **40 TIMES** ▼

Fitbit didn't track sleep periods on a train. **0 TIMES** ▲

2. GENETICS

23andMe / From £79 (special offers often available) / Turnaround: 2-3 weeks
Veritas Genetics / From $599 (£455 approx) / Turnaround: 2-3 months
Chronomics / £TBC / Turnaround: 2-3 months

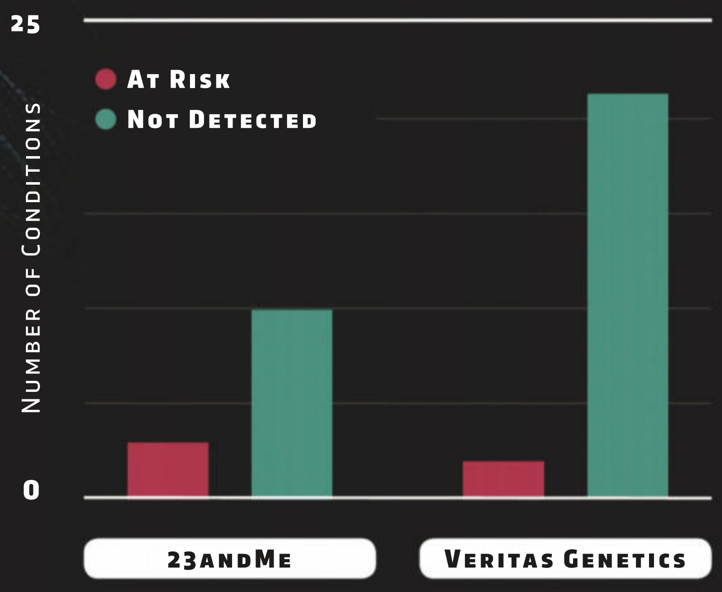
Genetic testing involves extracting DNA from cells of your mouth, found in the saliva sample you send to a lab, then detecting genetic variants by one of two methods. The first is genotyping, which cuts up DNA then adds the fragments to a microchip covered in fluorescent probes matching a selection of variants, like scattering glitter over paper dotted with glue to see what sticks. This is what 23andMe does. The second method is sequencing, which uses chemical analyses to read each letter in your DNA sequence. Whole-genome sequencing, done by Veritas Genetics, reads almost 6.4 billion letters along your 23 pairs of chromosomes.

Epigenetic testing is like genetic sequencing, except DNA is first chemically treated to highlight the location of 'epigenetic marks' along your chromosomes. Those marks are often chemical tags attached to DNA controlling whether genes are turned on or off, analogous to using a pencil to cross-out a few sentences or even entire pages in your body's instruction manual. As environmental factors like smoking affect whether you have marks at certain points on DNA, epigenetics can indicate your current health status. One firm, Chronomics, uses the presence of epigenetic marks on specific genes to estimate your 'biological age'.

DISEASE RISKS

Your risk of developing a disease is estimated from whether the genetic variants you carry are common within a database of people with similar demographics. Both 23andMe and Veritas Genetics predict that I have an increased risk of late-onset Alzheimer's disease (they predicted 20-25 per cent risk for me, versus 10-14 per cent for men) which worried me as my paternal grandfather developed dementia. But the environment should also affect my chances. "There are other things that need to happen in order for that disease to manifest itself," says Rebecca Hodges, lead genetic counsellor at Veritas.

Sequencing generates a massive amount of data: if your DNA letters were printed on paper, genotyping would cover hundreds of pages while sequencing would mean thousands of books. Genotyping is also a one-off test while sequencing lets you re-read DNA to identify more variants later. In some cases, like susceptibility to cancer, you may be able to take action to help prevent disease. Veritas's standard package scans for variants in 59 genes associated with conditions the American College of Medical Genetics and Genomics considers 'actionable'– the challenge is understanding how your variants are relevant, says Hodges. "We have a team of curators that look at these variants."

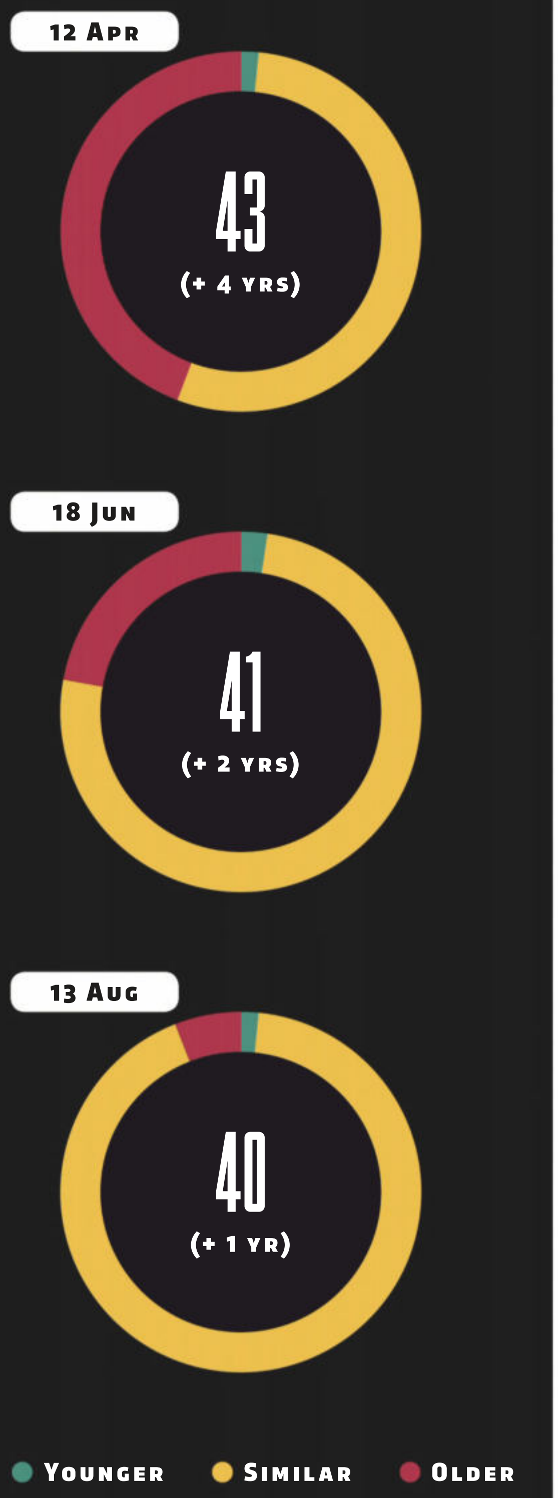


INHERITED TRAITS

23andMe provides eight results for 'Wellness' (how variants might affect your body's response to food or exercise) while Veritas's premium package (which scans 566 genes) files non-medical traits under 'Other' risks. Both firms claim that I'm intolerant to lactose, the sugar found in dairy products, which can lead to diarrhoea if left undigested. But while my cells don't make the enzyme required to digest lactose, gut bacteria will break it down and release gas, which is why lactose intolerance causes bloating and flatulence. While I haven't noticed such effects, I've switched from cow's milk to soya.

BIOLOGICAL AGE

Chronomics displays a headline figure for 'Biological Age' – how old your body truly is in years – and the difference from your chronological age. The figure is calculated by reading epigenetic marks at 20 million locations to study the patterns of where those marks on DNA are lost and gained over time. Another way to estimate age is from 'telomeres', protective caps at the ends of chromosomes, which get shorter as cells divide. But that approach doesn't consider how genes on chromosomes affect ageing, argues Chronomics CEO Dr Tom Stubbs, "Epigenetics is capturing more aspects of biological age than just telomere length."



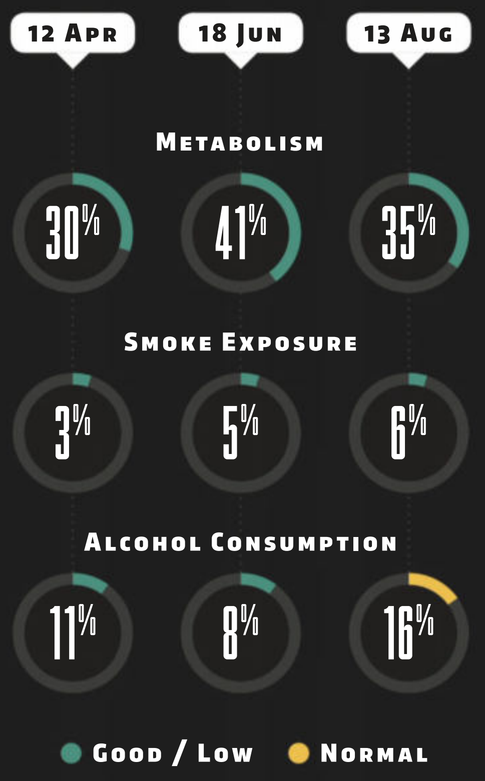
CHROMOSOME AGEING

The epigenetic marks used to calculate 'Biological Age' can be grouped according to whether they're located on a chunk of DNA that contributes to being younger, similar or older than your chronological age. Chronomics draws those chunks on a map of 23 chromosomes (representing pairs) coloured by age group. The company doesn't yet show specific genes, but did provide a few examples upon request.

- **ELOVL2:** This gene is involved in producing beneficial polyunsaturated fatty acids and gains epigenetic marks with age, turning the gene's activity off.
- **AHRR:** This gene is used to metabolise toxic hydrocarbons from cigarettes or air pollution and loses epigenetic marks with age, turning its activity on.

EPIGENETIC INDICATORS

Whereas genetic mutations that alter DNA letters are relatively rare, epigenetic marks are continuously added and removed throughout your lifetime. Whether your DNA has certain marks is influenced by the external environment, so epigenetics can indicate internal changes that influence health. Using information that you provide (including mass, diet and exercise), Chronomics compares your marks to people with similar demographics to set a baseline for what you would expect to see in an unhealthy person (a score of 100 per cent) then calculates the state of your metabolism, smoke exposure and alcohol consumption. Almost all my scores reflect the fact I'm a non-smoker, healthy weight, and drink responsibly.



RESULTS

The most surprising figure from my daily activity is that, on average, I only slept 5.6 hours a day (p70). As a consequence I now lie awake at night, worrying about how I should be asleep. I'm not alone: in 2017 Dr Kelly Baron, a psychologist specialising in behavioural sleep medicine at the University of Utah, described a condition called 'orthosomnia' where people obsessively track their sleep and fret about how much they get. "We defined orthosomnia as overemphasis or a fixation on having perfect or 'right' sleep," says Baron, who thinks the public health benefits of trackers outweigh such costs. "There's a potential to use these devices to increase sleep duration."

Another thing that might make you anxious about biometrics is wondering if a DNA test will uncover inherited conditions, which has implications for, say, whether you can get life insurance (p72). My results for genetic variants that might raise the risk of disease were a relief (I probably won't die tomorrow) and my epigenetic tests also show that my 'biological age' matches my chronological age.

Metabolism, as measured via markers in my blood (p75), also suggest that I have good overall health. My biggest concern was high levels of LDL or 'bad' cholesterol – a risk factor in atherosclerosis, a cardiovascular disease where the inside of arteries become narrow due to the build-up of plaques containing cells, fats and other material. Doctors want your LDL concentration to be below five millimoles per litre, and blood tests highlighted my level as 'highly abnormal'. But Dr Louisa Loughborough, my GP, disagrees. Hovering above five is "Ever-so-slightly raised," she says. "Don't worry about it."

It's less obvious how to interpret data from your gut. While there's plenty of evidence that bacteria are somehow linked to disease risks, it's unclear what 'Microbiome Protection Level' scores actually mean in terms of cause and effect (p74). Similarly, there's no doubt that high microbiome diversity is beneficial to the human body, but adding desirable species isn't straightforward (my genetic tests revealed lactose intolerance, for instance, so probiotic yoghurt isn't ideal). Nonetheless, changing habits is a low-risk health intervention, so I now avoid snacks containing refined sugar in favour of dried fruit and nuts.

3. MICROBIOME

Atlas Biomed / From £99 / Turnaround: 2-6 weeks

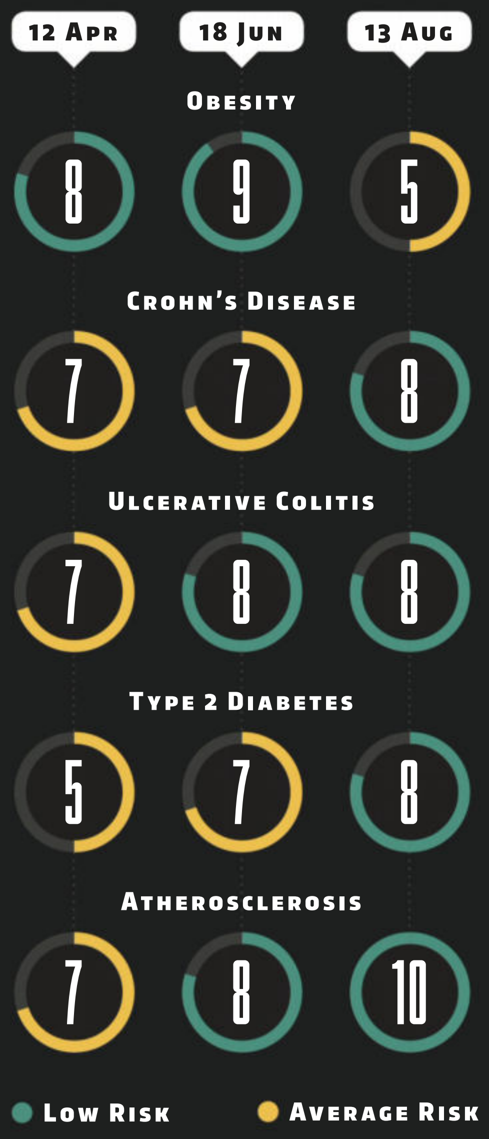
The community of microorganisms that colonises a human body – the 'microbiome' – includes everything from bacteria and viruses to fungi. The microbiome contains hundreds of species of bacteria and individual microbes outnumber human cells by a ratio of (at least) 1.3 to 1. Your microbiome interacts with the body, which influences your physiology. Research suggests that a richer and more diverse microbiome is linked to a lower risk of disease.

Microbiome composition is unique to each individual. Atlas Biomed reads genetic sequences to determine the identity and proportion of the various bacteria that inhabit your gut. After following handy instructions explaining how to sit on a toilet to 'deposit sample', you pop your poo in the post then wait for a report on Atlas Biomed's website or app, which will later give a list of microbes and their relative abundances, plus scores related to health and nutrition.

The most important score is for 'Microbiome Diversity Level', which is higher in individuals on a plant-based diet. Food fibres are complex carbohydrates such as cellulose (found in nuts and wholegrain cereals, for example) that are digested to nourish microbes within the gut ecosystem. "It's not that we're promoting a vegetarian lifestyle," says Dr Dmitry Alexeev, Atlas Biomed's head of microbiome research, "but we are trying to teach people about the importance of fibre."

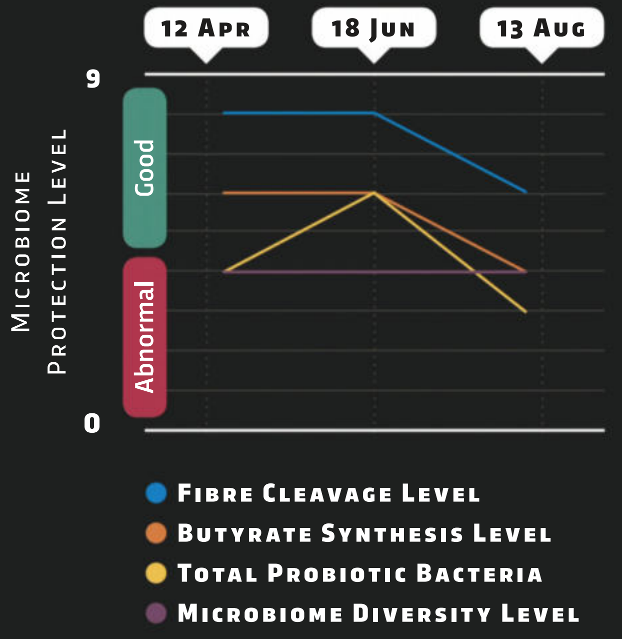
DISEASE RISKS

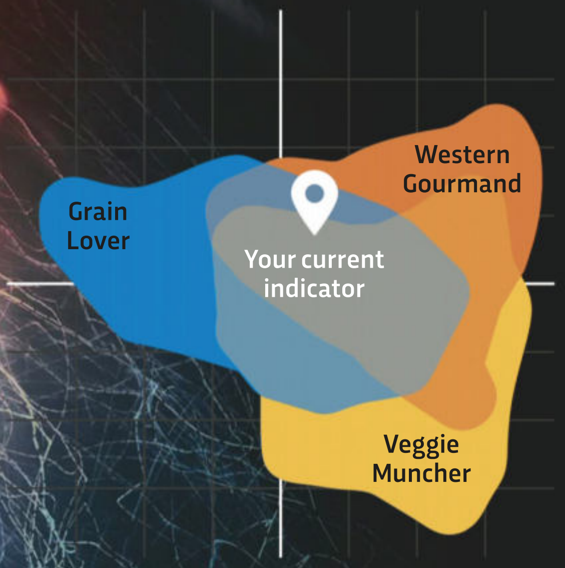
Atlas Biomed gives risk scores that indicate how gut bacteria work with your body to protect against diseases. The five scores for 'Microbiome Protection Level' are on a relative scale of 1-10, normalised so 5 is average for the UK population. My scores suggest I have a low risk of developing five conditions.



NUTRITION

Bacteria break down dietary fibres and synthesise short-chain fatty acids such as butyrate, a source of energy for the gut ecosystem. High microbiome diversity makes that ecosystem dynamic yet stable, forming a buffer against opportunistic pathogens like *E. coli*, which can cause inflammation of the protective 'mucous layer' lining your gut. Metabolic products like butyrate, produced by beneficial bacteria and other 'probiotic' microbes, can therefore be a sign of inflammatory conditions ranging from irritable bowel syndrome (IBS) to Crohn's disease. Atlas Biomed shows scores for probiotics, diversity and fibre metabolism. As my levels were all low or average, I should eat more vegetables to support my microbiome.





ENTEROTYPE

Microbiome composition can be classified into three clusters or 'enterotypes', each characterised by the presence of certain bacteria. Because they're linked to diets in different parts of the world, Atlas Biomed calls the types 'Western gourmand', 'Veggie muncher' and 'Grain lover'. The icon representing my type – Western gourmand – is apt because it's my favourite food: pizza.

4. METABOLISM

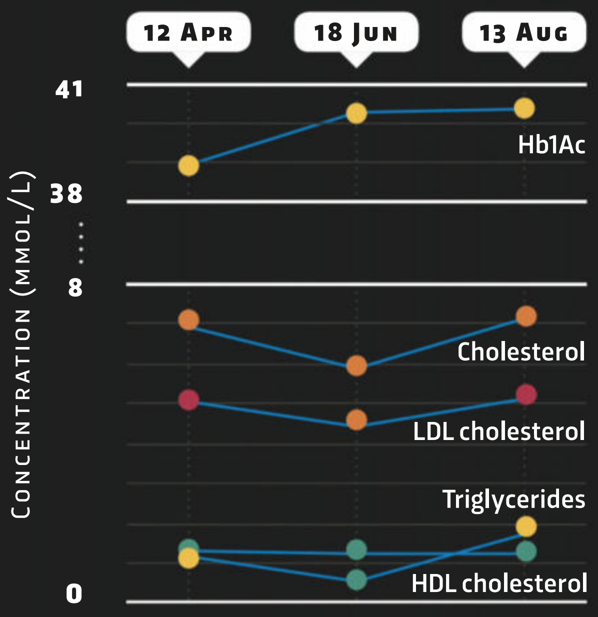
Thriva / From £24 / Turnaround: 1-2 weeks

The conventional way to assess health is through a blood test, sending your sample to an analytical chemistry lab to measure levels of biomarkers such as lipids (markers for cardiovascular disease). Until recently that meant visiting your GP, who checks things like blood pressure before deciding whether to order a test. But companies like Thriva are now putting the power in your hands. Using a disposable lancet, you prick a fingertip then collect your blood sample in one to two tubes. Be warned that if you want to test multiple markers, your blood will probably clot before you can fill a second tube (I tested over 20 different biomarkers so ended up having blood drawn via syringe at my local clinic).

Doctors will often check for signs of 'metabolic syndrome', a loose term for the combination of conditions that include obesity and diabetes. Your GP might plug factors like blood pressure and cholesterol levels into an equation to calculate your 'QRISK score', which predicts your risk of having a heart attack or stroke within the next 10 years. My score is 1.4 per cent. At over 10 per cent, your GP may prescribe a statin to lower cholesterol. Personal blood tests provide many of the metrics needed to calculate scores yourself (**qrisk.org/three**).

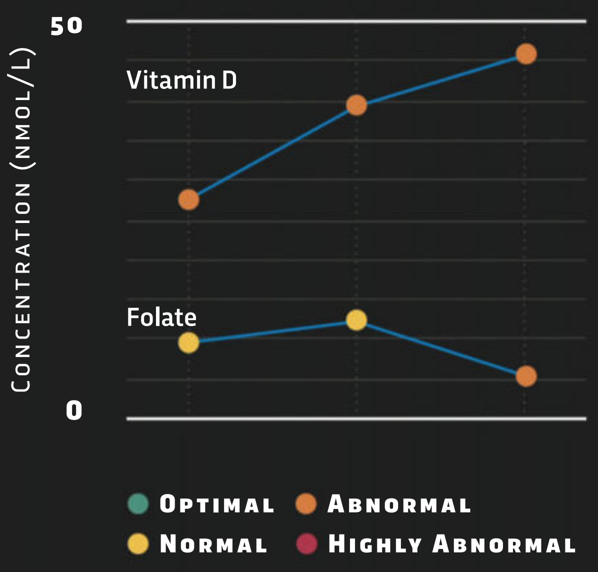
LIPIDS

Fatty biomolecules come in various forms, from simple triglycerides to complex cholesterols, most notably HDL (high-density lipoprotein) – also known as 'good cholesterol' – and LDL (low-density lipoprotein) aka 'bad cholesterol'. Results from blood tests show that intensive exercise over summer caused a clear drop in my levels of unwanted LDL (without affecting HDL), demonstrating that increased physical activity helps fight circulating body fat. For comparison, this line graph also plots HbA1c concentration, a measure of glucose that's attached to haemoglobin, which indicates blood sugar and serves as a marker for diabetes.



VITAMINS

Vitamin B9 or 'folate' is vital for maintaining DNA. My folate level only became abnormal in the final test, while my active B12 (not shown) was always normal. I can increase folate simply by eating more leafy vegetables. Vitamin D is made by your skin upon exposure to sunlight and lets the body absorb calcium, which is essential for building bones, muscles and immune function, and helps to prevent depression. My vitamin D level was consistently low. Doctors say to get extra sunshine if your concentration is less than 50 nanomoles per litre, but mine is 45.8 (moderate deficiency), so my GP prescribed supplements.



CONCLUSIONS

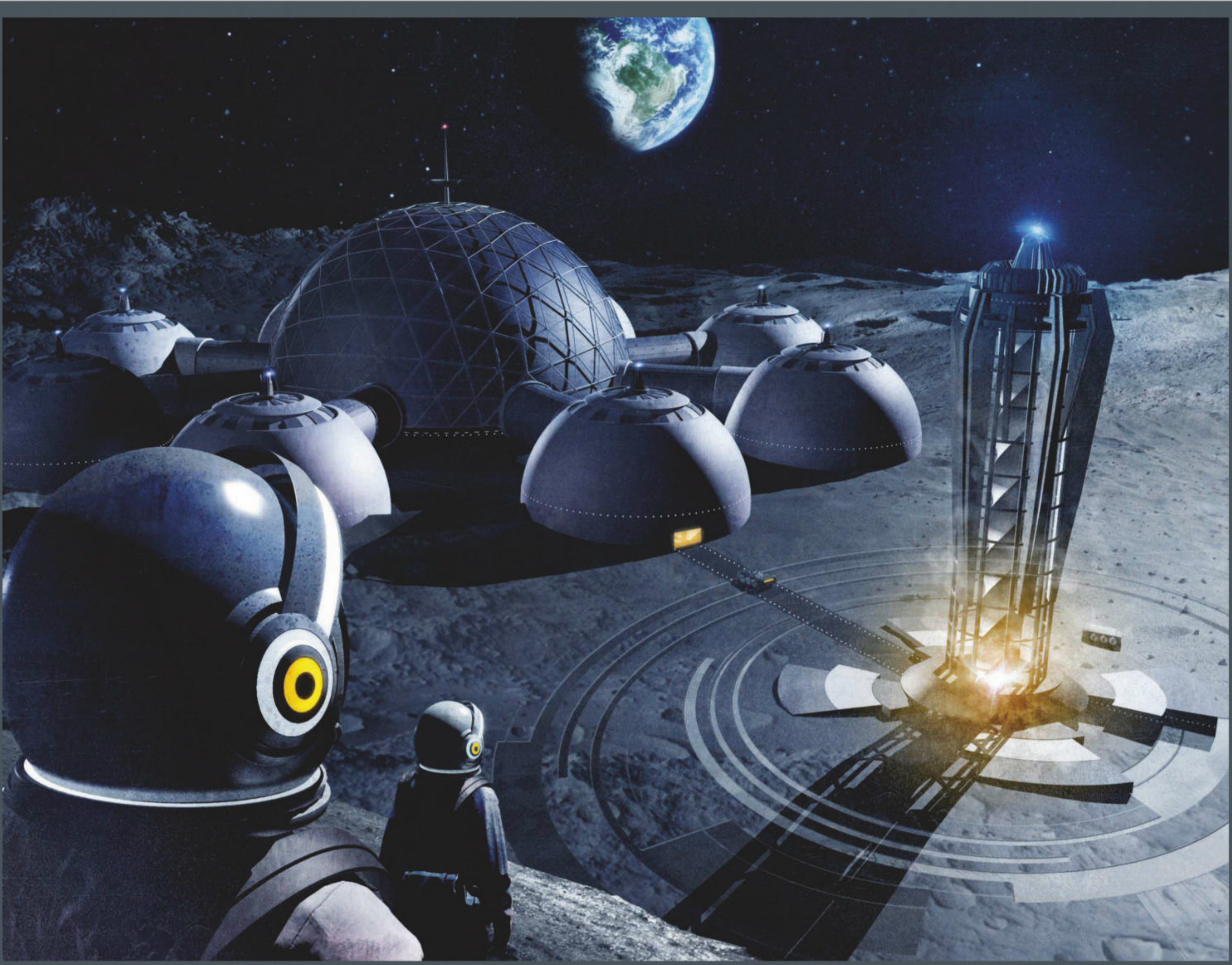
So which metrics are worth measuring? Each test has pros and cons. Some Fitbit users are motivated by goals like 10,000 steps a day, others will be demoralised when they miss such targets, while people like me won't care about beating their personal bests. Sleep tracking is a double-edged sword: you'll gain awareness of sleeping patterns, but might also lose sleep over whether you've slept enough.

With DNA tests, 23andMe shows clear text and colourful diagrams but misses many genetic variants, while genome sequencing is a trade-off between choosing firms like Veritas Genetics to survey and interpret your variants versus downloading your own data, as offered by firms like Dante Labs, which sequences your genome for a similar cost but automates the interpretation. Epigenetics has potential to provide actionable information, but Chronomics doesn't yet present your results in an intuitive way.

Blood tests for metabolic markers reveal your current risk factors for future disease, but the charts include a hint of scaremongering and Thriva shifts the responsibility of interpretation from their doctors to your GP. Improving your diet should boost your microbiome, but won't necessarily protect you from illness.

While I wouldn't give any biometric test a top rating, each has features that should be useful to someone, depending on your personal risk factors. After half a year of self-tracking, an annual health checkup already feels like an outdated system of measurement. It won't be long before we all go metric. **SF**

by **DR JV CHAMARY**
(@jvchamary)
JV is a science communicator with a PhD in molecular evolution and genetics.



WHAT IF... (WE MINED THE MOON?)

WORDS: **DR STUART CLARK**
ILLUSTRATIONS: **ANDY POTTS**

THE MOON IS ABUNDANT IN NATURAL RESOURCES. BUT WHAT WOULD HAPPEN IF WE WENT THERE AND EXTRACTED THEM?

Thanks to our exploration of the Moon over the past decades, we now know that it is a potentially huge repository of natural wealth.

For a start, there appears to be abundant water ice at the Moon's south pole – crucial for setting up lunar bases or colonies. There are rare-earth metals such as neodymium and lanthanum, which are used in technologies like speakers, smartphones, batteries and camera lenses, and there are plenty of other useful metals, such as silicon, titanium and aluminium. What's more, it's thought that the Moon's surface has a relatively high concentration of a rare isotope of helium called 'helium-3', which could be used to power future nuclear fusion reactors. Companies are already drawing up plans to develop the technology to mine the Moon. But what would be the consequences of going after these resources?

1 There could be a lunar 'gold rush'

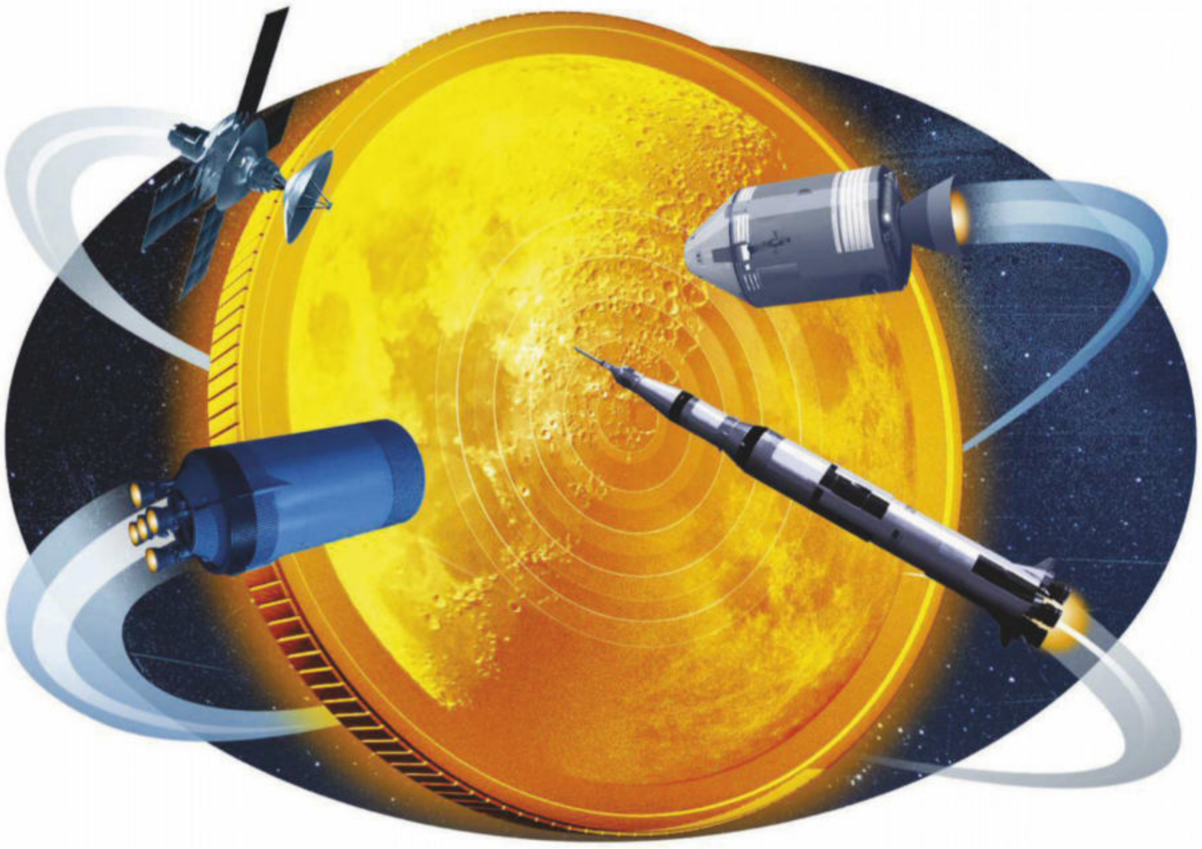
A Moon race is hotting up again. This time, it's not just between the US and the USSR, as it was in the 1960s. Instead, many countries, such as India and China, are involved, as well as private companies such as SpaceX in America and SpaceIL in Israel.

They are interested in finding a way to build a presence on the Moon that will be sustainable over the long-term. And they are also interested in whether mining the Moon can be a feasible economic prospect. Strikingly, there is little international law to regulate this endeavour.

The so-called Moon Treaty was opened for countries to sign in 1979. It tried to protect the Moon by calling for it to become the 'common heritage of mankind'. But although the treaty became active in 1984, no major space-faring power has ever signed it – the US, UK, Russia, China and Japan are all notable by their absences.

This lack of take-up is largely because 'common heritage' implies shared ownership and the equitable distribution of resources. So, the proceeds from the sale of any resources mined on the Moon would have to be equally distributed around the Earth, rather than kept by the country or company that extracted them. And very few countries, it seems, are willing to sign away their profits for the common good.

What's unfortunate is that the treaty also called for an international body to govern the exploitation of the Moon's natural resources. Without such regulation, a winner-takes-all mentality could take hold, leading to a kind of lunar 'gold rush' by the countries and companies that can afford to make the trip.



2

We could get to Mars quicker

All you need to manufacture rocket fuel is water. A process called 'electrolysis' splits water into hydrogen and oxygen, which can together be used as fuel. And if we are going to attempt a mission to Mars, then we're going to need a lot of fuel.

Manufacturing the fuel on Earth may seem like the obvious answer, but it then needs to be launched into space. To overcome our planet's massive gravitational field, rockets must reach speeds of 11km/s (25,000mph), and that takes a lot of money. The Moon, though, has only one-sixth the gravity of the Earth, and so fuel could be launched a lot more cheaply once it has been made.

In 2017, students involved in the Caltech Space Challenge proposed designs for a lunar launch and supply station for deep space missions. The idea was to mine ice on the Moon and launch it to an orbiting lunar 'gas station'. The station would then transform it into hydrogen-oxygen rocket fuel and transfer it to long-distance spacecraft, such as those expected to be going to Mars in the 2030s. However, Dr Robert Zubrin, president of space tech company Pioneer Astronautics, and a long-time advocate of Mars exploration, thinks that this is a circuitous route, and would cost more in the long-run. "The propulsion requirements to go to the Moon to get [the lunar rocket fuel] are greater than those for flying directly to Mars," he says.

3

We could lose a valuable scientific resource

The Moon is a scientific time capsule. As it lacks an atmosphere, there is no weathering or erosion of its surface. The cratered face we see represents 4.5 billion years of astronomical history. We've lost that ancient geological record on Earth because of erosion and the endless recycling of the planet's crust via plate tectonics. Could mining cause the Moon to go in the same direction?

Even before we get to the mining stage, the mere act of setting up a lunar base for mining operations will involve destroying large quantities of the lunar soil ('regolith') to make way for buildings, or to make the building material itself. Any of the destroyed rocks could contain valuable geological clues as to how the Moon, and by extension the Earth, formed.

But it's not just scientific knowledge that could be lost. The early Space Age landing sites on the Moon, such as the Apollo landing sites, are now culturally significant sites. "As soon as we start more regular trips to the Moon, we run the risk of destroying these sites," says Dr Alice Gorman, a space archaeology expert at Flinders University, Australia. Even if we don't damage the sites directly, Gorman points out that the dust thrown up by the landers could erode or cover the sites, erasing the famous bootprints left by the astronauts, for example.

Every society has its own way of relating to the Moon – and that will inevitably change as we start to mine it. "I don't believe that things should always stay the same," says Gorman, "but we do need to think about these things, and make informed decisions."

4

The Moon could declare independence

In 1967, the Outer Space Treaty became a part of international law and banned countries from claiming ownership of any celestial body. This meant that neither the Soviets nor the Americans could claim sovereignty when they landed on the Moon. But what about settlers on the Moon banding together to declare their own independence? Prof Christopher Newman, space law expert at Northumbria University, thinks it unlikely, at least in the first instance.

"The Moon is close and connected to the Earth, so I think we are going to see a bleeding over of terrestrial nation states onto the Moon, rather than a separate lunar colony establishing its own identity," he says.

Although this at first seems to go against the principles of non-ownership enshrined by the Outer Space Treaty, there is an obvious way it might happen. Each nation will want to build its own infrastructure and will most likely concentrate its efforts into specific places. "Although there will be no sovereign claims to ownership of those regions, there will effectively be zones of influence," says Newman.

However, if mining takes off and becomes prosperous, things could change completely. The country zones could start to merge as activities expand, and the old national bonds could start to feel less important. In this way, a lunar culture distinct from Earth's could develop, and as soon as the lunar colonists decide they have more in common with each other than with any one nation on Earth, independence could become an option.

by **DR STUART CLARK**
(@DrStuClark)
Stuart is an astronomy writer and journalist. His latest book is The Unknown Universe *(£14.99, WW Norton).*

5

We could reverse climate change

There is one thing that the Moon has in absolute abundance: dust. And it's a total nuisance. It's highly abrasive, so it wears down surfaces and damages seals. It's dark and clingy, so coats anything that's taken outside, and it's toxic as well, posing a health hazard to any astronaut who inhales quantities of the stuff. "The dust is one of the greatest unsolved problems in returning to the Moon," says Gorman.

But there might be an overwhelmingly positive use for this all-pervasive powder: saving the Earth from climate change. In 2007, astrophysicist Prof Curtis Struck at Iowa State University looked into the feasibility of using the dust to shade the Earth from the Sun's light. As a last resort to combat global warming, sunshades in orbit around our world could cut down the amount of energy we receive from the Sun. Struck suggested that these sunshades could be nothing more complicated than clouds of lunar dust transported from mines on the Moon and dumped into strategic places in orbit. There would be downsides. Struck pointed out that the clouds would scatter the Sun's rays and therefore make night on Earth brighter, producing more light than the full Moon. But as he writes in the closing lines of his paper: "Humanity has already made changes that adversely affect the global environment of Earth. With the methods described above we may be able to do so in ways that improve that environment." Even so, we'll file this one under 'desperate measures'. **SF**

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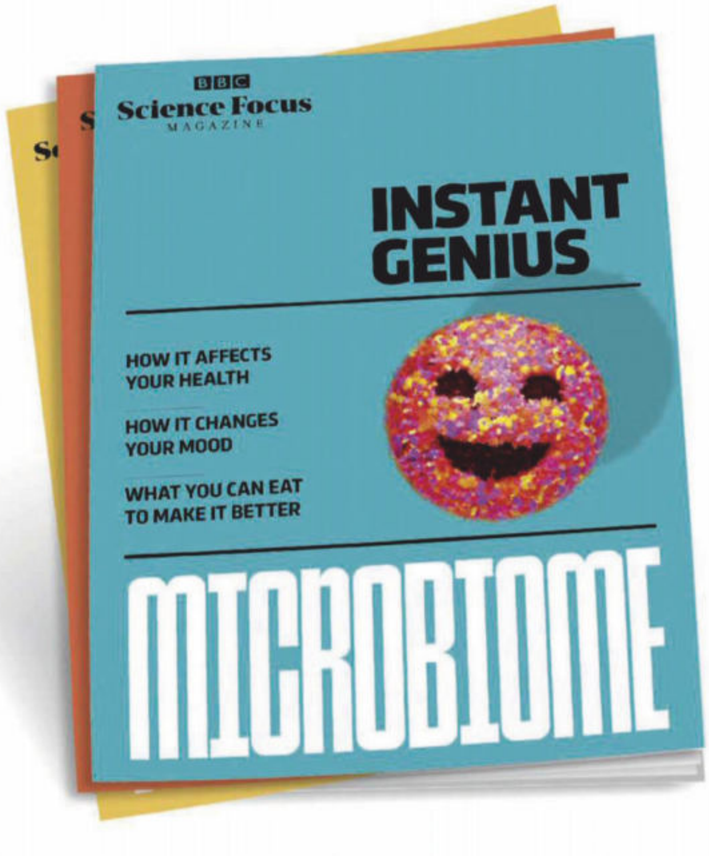
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PROF ALICE GREGORY	Psychologist, sleep expert
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DR HELEN PILCHER	Biologist, science writer
PROF ROBERT MATTHEWS	Physicist, science writer

PAUL MELLOR, ST ALBANS

WHAT IS THE QUIETEST NATURAL LOCATION ON THE SURFACE OF THE PLANET?

There are many regions on the planet that are remote enough for you to escape all the noise of human civilisation. England's most tranquil place, according to the Campaign to Protect Rural England (CPRE), is a 500m-by-500m patch of bogland in Kielder Mires, Northumberland. But tranquil is not the same as silent: even this ungrazed wilderness still has the sound of wind and the occasional bird. In fact, being able to hear birdsong was one of the factors that the CPRE included when calculating a place's tranquillity score.

To escape wind and birdsong, too, you need somewhere barren and sheltered, such as the crater of a volcano. One good candidate is the Haleakalā crater on the Hawaiian island of Maui (pictured), which has been dubbed the "quietest place on Earth". Here, the sound level is just 10 decibels – the same volume as your own breathing – and is probably as quiet as anything you can experience. ***LV***

GETTY IMAGES

SUSAN SMITH, LICHFIELD

DO ANY MAMMALS OTHER THAN HUMANS HAVE ‘WHITES OF THE EYES’?

The white of the eye – or the ‘sclera’ to give it its technical name – is the opaque, protective layer that encloses the entire eyeball, apart from the transparent cornea at the front of the eye. In humans, the whole sclera is white, but most mammals have a sclera that is dark at the front, or coloured to match the iris, with just a narrow band of white sclera occasionally visible.

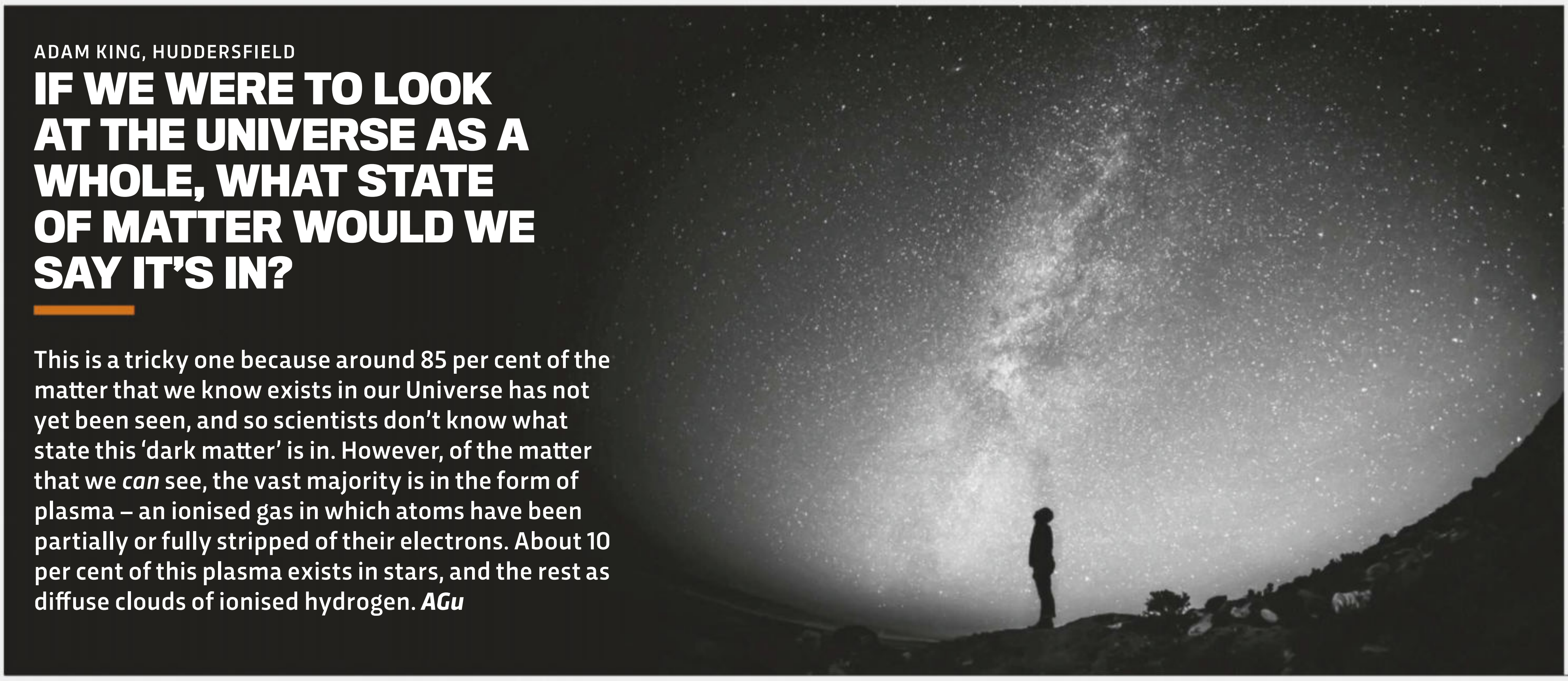
The dark sclera in most mammals might have evolved to ensure a flash of white from their eyes wouldn’t draw attention to them as they lurked in the shadows. But in humans, our eyes may have evolved a white sclera since it made it easier to see which direction we’re looking in. This ‘cooperative eye hypothesis’, originally proposed in 2001 by researchers at the Tokyo Institute of Technology, suggests that being able to quickly tell the direction of someone’s gaze is an important part of non-verbal communication. This may have been useful to our ancestors when hunting in groups – a quick flick of the eyes from one hunter would be enough to alert the others that they had spotted something. Surprisingly, though, eyes with a white sclera are rare among the other great apes. This may be because their societies are less cooperative, and it’s more important to *hide* the direction of gaze from each other, so as not to give away the location of food, for instance.

Other studies have found that, among canines, those species who hunt in groups are much more likely to have eyes with a white sclera than those who hunt alone. But gaze signalling is not the only possible reason for the white sclera in humans and some animals. It may also have evolved as a way to signal physical health – diseases such as hepatitis can discolour the sclera yellow. ***LV***

DILEEP BAGNALL, LANCASHIRE

WHAT IS THE LARGEST KNOWN CELESTIAL BODY?

The largest known ‘object’ in the Universe is the Hercules-Corona Borealis Great Wall. This is a ‘galactic filament’, a vast cluster of galaxies bound together by gravity, and it’s estimated to be about 10 billion light-years across! However, this is not really a ‘celestial body’ – a term which normally implies a tightly-bound object like a star or a galaxy. The largest known elliptical galaxy is thought to be IC 1101 (with a diameter of four million light-years), and the largest known spiral galaxy is Malin 1 (with a diameter of 650,000 light-years). Meanwhile, the largest star by radius is thought to be UY Scuti, a red hypergiant star in the constellation of Scutum that has an estimated radius of over a billion kilometres – 1,700 times that of the Sun. *AGu*



ADAM KING, HUDDERSFIELD

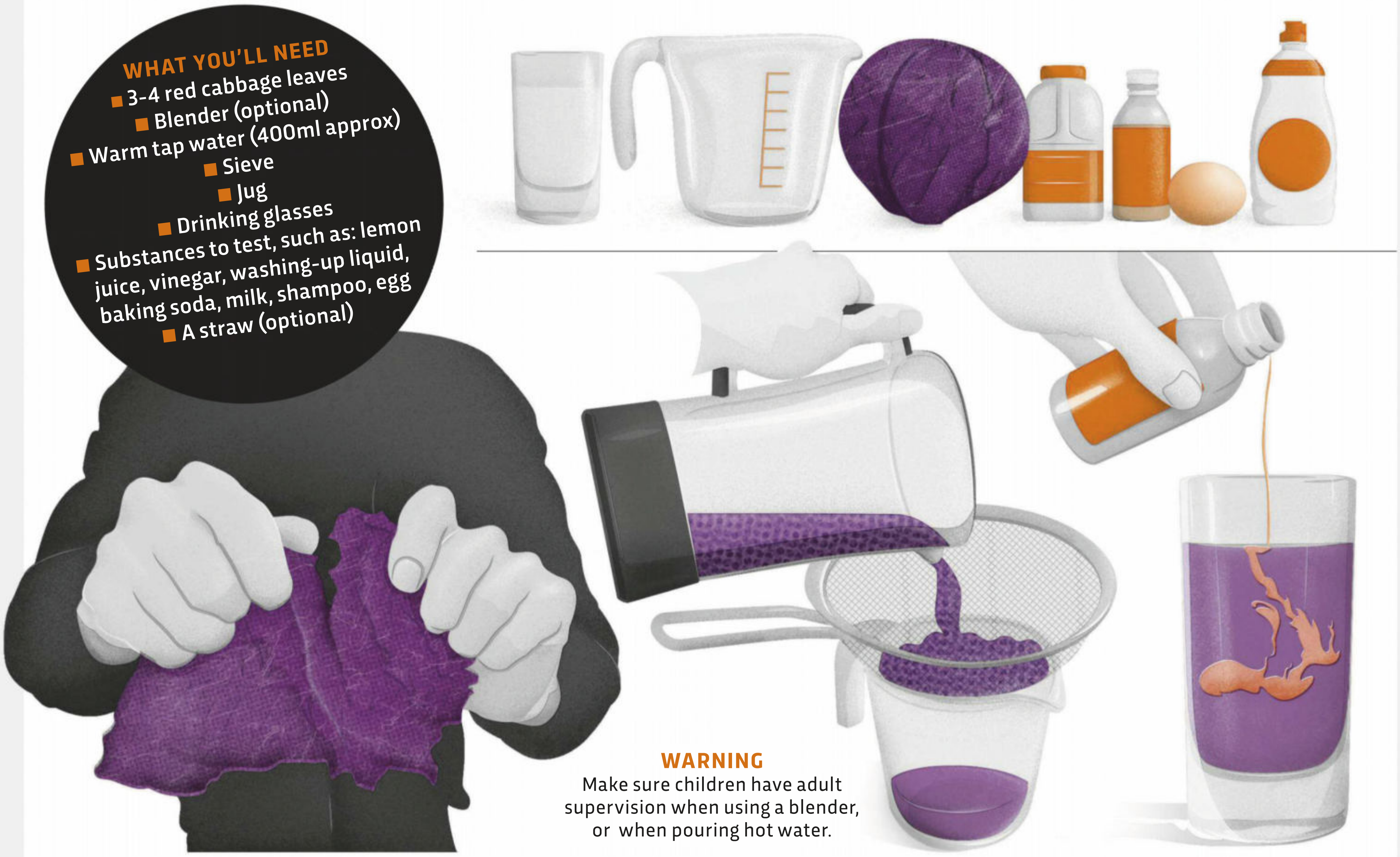
IF WE WERE TO LOOK AT THE UNIVERSE AS A WHOLE, WHAT STATE OF MATTER WOULD WE SAY IT’S IN?

This is a tricky one because around 85 per cent of the matter that we know exists in our Universe has not yet been seen, and so scientists don’t know what state this ‘dark matter’ is in. However, of the matter that we *can* see, the vast majority is in the form of plasma – an ionised gas in which atoms have been partially or fully stripped of their electrons. About 10 per cent of this plasma exists in stars, and the rest as diffuse clouds of ionised hydrogen. ***AGu***

DIY SCIENCE

RED CABBAGE PH INDICATOR

We'd love to see pictures of your experiments. Send them to us on Facebook or Twitter (**@sciencefocus**) and we'll share our favourites!



WHAT YOU'LL NEED

- 3-4 red cabbage leaves
- Blender (optional)
- Warm tap water (400ml approx)
- Sieve
- Jug
- Drinking glasses
- Substances to test, such as: lemon juice, vinegar, washing-up liquid, baking soda, milk, shampoo, egg
- A straw (optional)

WARNING

Make sure children have adult supervision when using a blender, or when pouring hot water.

WHAT TO DO

1. Tear up cabbage leaves and place in blender.

2. Cover cabbage leaves with the warm water.

3. Blend cabbage and water until the water turns dark purple. (If you don't have a blender, finely chop the cabbage leaves and pour boiling water over them. Allow to cool before sieving into a jug. Go to step 5.)

4. Pour contents of blender through sieve, keeping the purple liquid in a jug.

5. Pour about 50ml of the purple liquid into a glass and add some vinegar. The liquid will change colour!

6. Repeat step 5 with the other substances, using a fresh glass for each one. See if you can work out which are acids, and which are alkalis.

7. If you're feeling adventurous, you can also pour a little of the cabbage juice into a glass and use a straw to blow some bubbles through it for about a minute. The juice will gradually change colour!

WHAT'S HAPPENING

Red cabbage gets its purple colour from a type of natural pigment known as an 'anthocyanin'. Blending the cabbage leaves with warm water is a quick way to extract this pigment by making it easier for it to dissolve in water.

Anthocyanins change their colour depending on the pH of the solution they are in, which makes them useful as a pH indicator in chemistry. The pH scale is a measure of how acidic or alkaline a substance is. The scale goes from 0 to 14, with 0 being the strongest acid, 7 being neutral, and 14 being the strongest alkali.

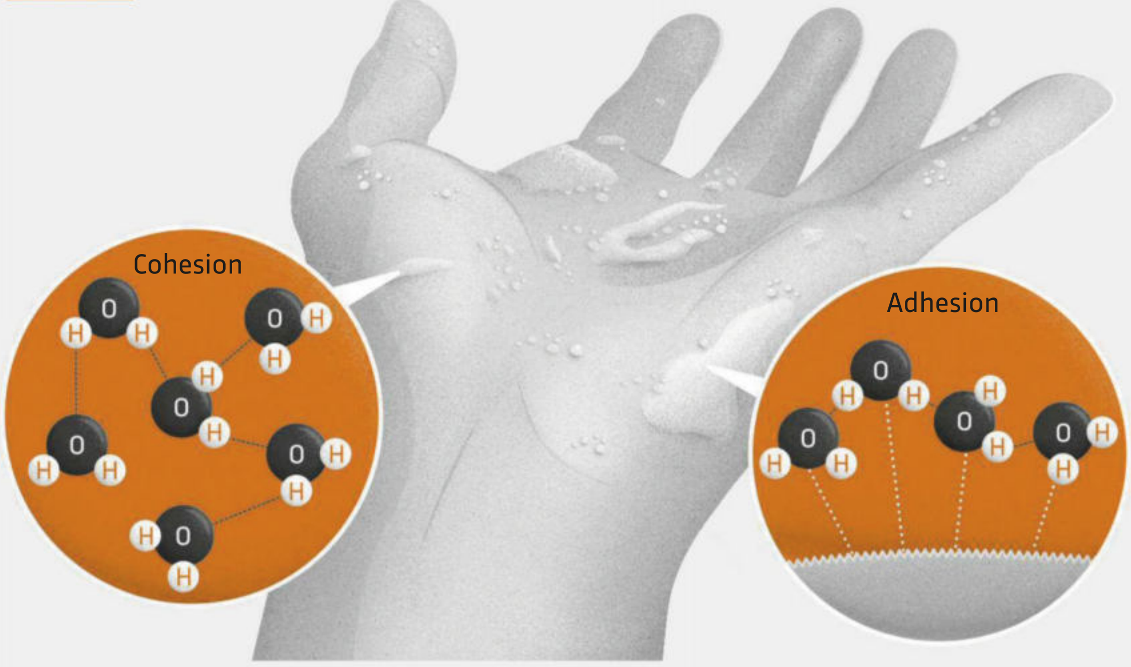
The anthocyanins in red cabbage are purple in neutral solutions such as water, but turn pink or red when mixed with acidic substances like lemon juice or vinegar, and they turn blue, green or yellow when mixed with alkaline substances such as baking soda and washing-up liquid.

Blowing bubbles through the solution causes carbon dioxide from your exhaled breath to react with the water to form weak carbonic acid. The colour change from purple to pink happens gradually as the solution becomes more acidic. ***AS***

GETTY IMAGES X2 ILLUSTRATION: DAN BRIGHT

ANDREW DALTON-GILL, HAMPSHIRE

WHY DOES A LITTLE BIT OF MOISTURE MAKE YOUR HANDS STICKY, BUT A LARGE AMOUNT MAKES THEM SLIPPERY?



There are two effects at work. First, 'cohesion': the attraction of water molecules to each other. This comes from the opposing electric charges on the hydrogen and oxygen atoms of neighbouring H_2O molecules. And it's this mutual attraction of water molecules in the damp layer on the skin that creates the feeling of stickiness. We only feel it, however, because that layer stays on the hand through the second effect: 'adhesion', by which water molecules stick to the surface of other substances. When your hands are soaked, there are more water molecules to adhere to the microscopic crevices in your hands, which reduces friction and makes them slippery. ***RM***

AISSA RAFLA, VIA TWITTER

HOW IS SOUND CREATED WHEN TWO OBJECTS COLLIDE?

Sound is simply waves of pressure passing through a transmission medium such as water or air. The intensity – or loudness – of the sound depends on just how violently the material's molecules are jolted by the pressure waves. When a leaf falls to the ground, the impact injects relatively little energy into the surrounding air molecules, so the molecules don't move much. But when two hefty, fast-moving objects collide, the noise can literally be deafening. ***RM***

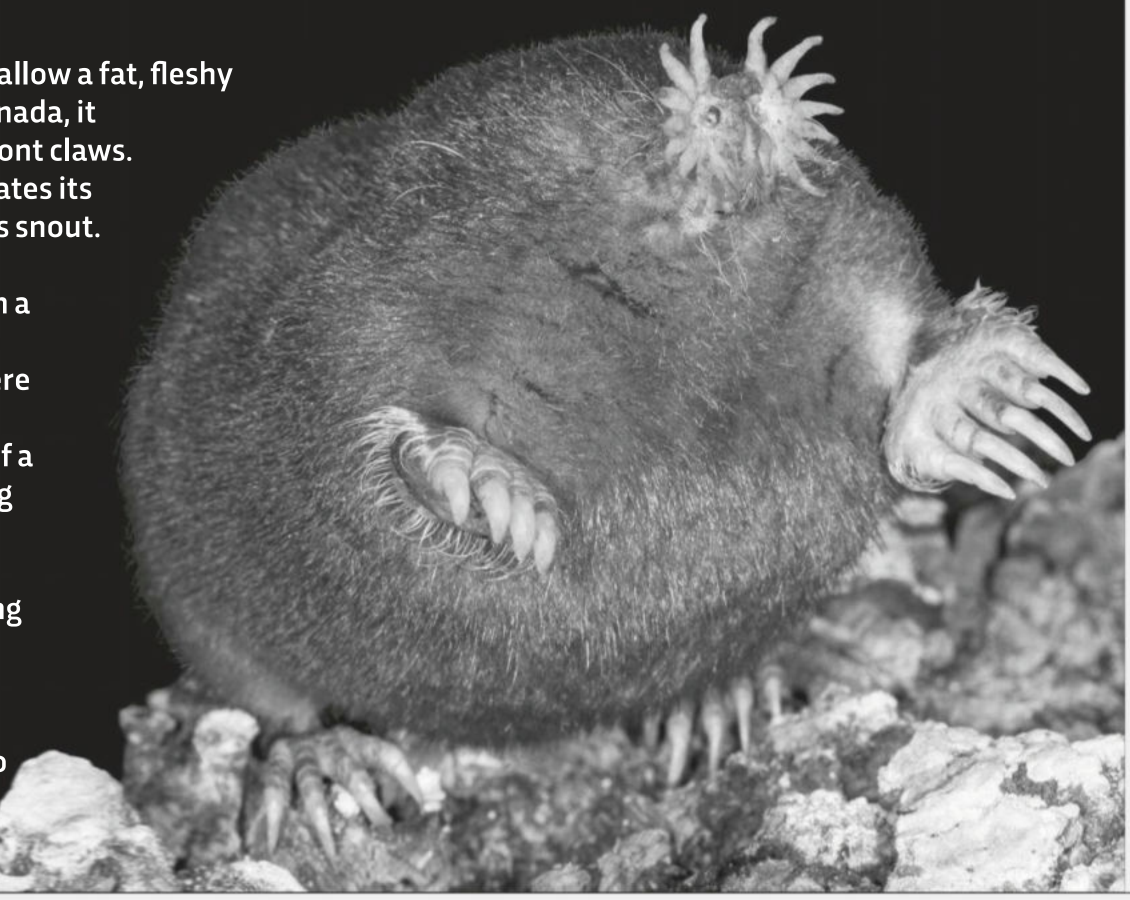
NATURE'S WEIRDEST CREATURES...

THE STAR-NOSED MOLE

This subterranean mammal looks like a furball trying to swallow a fat, fleshy spider. Native to the eastern parts of North America and Canada, it snuffles through the tunnels that it carves with its sturdy front claws. Living in the dark, its eyes are essentially useless, and it locates its prey via the 11 pairs of finger-like tentacles that surround its snout. This star-like appendage is densely packed with more than 100,000 nerve fibres, all squashed into an area smaller than a human fingertip.

Thanks to this sensitive touch organ, the mole takes a mere eight milliseconds to decide whether or not something is edible, identifying and eating a grub in less than a quarter of a second. So the next time you chide your teenager for bolting their meal, just be thankful they're not a star-nosed mole – the fastest eaters in the mammal kingdom.

The mole can also smell in underwater tunnels, by blowing air bubbles onto objects or scent trails and then re-inhaling the scented bubbles. Another of its quirks is that, during mating season, the testicles of adult males swell to take up around 10 per cent of their body mass. This would be akin to an adult human walking around with a bowling ball in their pants, which thankfully does not happen. *HP*

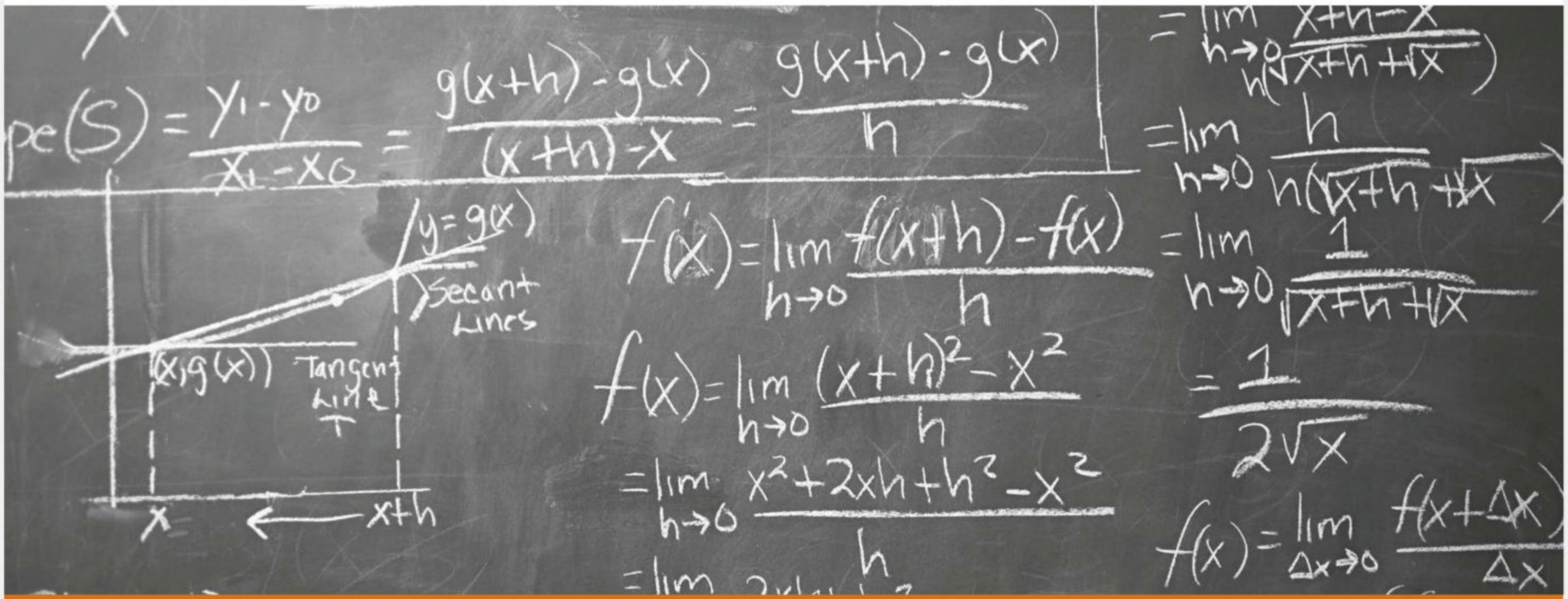


GETTY IMAGES X3, ALAMY ILLUSTRATIONS: DAN BRIGHT

CROWDSCIENCE

We've teamed up with the folks behind BBC World Service's *CrowdScience* to answer your questions on one topic. You can tune into *CrowdScience* every Friday evening on BBC World Service, or catch up online at **www.bbcworldservice.com/crowdscience**

WHAT IS MATHS?



IS MATHS A TOOL?

One way of seeing maths is as a tool that we harness to make our lives easier. Today, maths underpins everything from the functioning of our phones to the architecture of the buildings we live in. But it started out as something even more basic: as a way of keeping count. The earliest evidence for this is prehistoric tally sticks, such as the 'Ishango bone'. This 20,000-year-old baboon's bone was found in Central Africa, carved with what look like tally marks. Another useful tool came along in the 7th Century AD, when the Indian mathematician Brahmagupta formally wrote down the rules for computing with zero and negative numbers. This provided a way of quantifying an important real-world concept: debt.

The 20,000-year-old Ishango bone, notched with tally marks

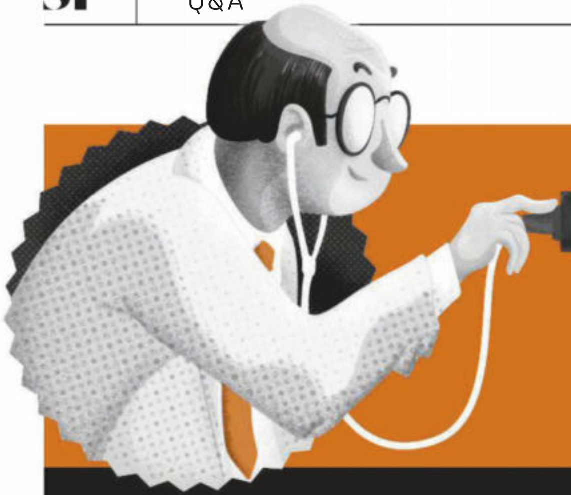
IS MATHS A LANGUAGE?

Just as conventional languages have an alphabet, vocabulary and grammar, so maths has the symbols 1-9, operators such as '+' and '÷', algebraic letters, and conventions on the correct way to write an equation or compute a sum. Maths today is a language that is 'spoken' around the world, regardless of nationality or geography. A key difference with the language of maths, though, is that there's an objectivity to it. Whereas two plus two will always equal four, the language of communication shifts over time and space, depending on how humans define and use it. New maths doesn't overwrite previous work – it just adds a new detail to our understanding of the abstract world of numbers.

IS MATHS OUR ENTIRE REALITY?

The idea that everything can be described and explained by maths can be traced back to the work of the Greek philosopher Pythagoras, who held that "all is number". We now know that our Universe is governed by the laws of physics, which can be expressed mathematically. This has led some, such as the cosmologist Max Tegmark, to argue that everything in the cosmos, from cells and particles, to giraffes and galaxies, cannot only be described in terms of maths, but is literally *made of* maths. Others point out, though, that maths struggles to describe some aspects of our lives, such as morality, emotions, or the colour yellow. The true relationship between maths and reality is a debate that's likely to rumble on for some time yet.

Marnie Chesterton is the presenter of *Is maths real?* – an episode of CrowdScience that can be streamed at **bbcworldservice.com/crowdscience**



DEAR DOCTOR...

DELICATE ISSUES DEALT WITH BY *SCIENCE FOCUS* EXPERTS

EVERYONE I KNOW LOVES LISTENING TO MUSIC, BUT IT DOES NOTHING FOR ME... WHAT'S WRONG WITH ME?

We tend to think of musical enjoyment as universal – after all, music features in every culture around the globe, and even tiny babies love jiggling and giggling along to a beat. But this sweeping generalisation ignores the approximately 5 to 10 per cent of people, like you, who have 'musical anhedonia' and derive no pleasure from music. So you are certainly not alone. People with musical anhedonia tend to be able to enjoy other aesthetic outlets, such as reading, films and art, and they don't have a problem comprehending music. They just have no emotional response to it (people with 'amusia', in contrast, have difficulty recognising musical tones, but can still be emotionally moved by music). Research into musical anhedonia is relatively new – the term was only coined in 2011. Initial findings suggest the roots of it lie with having weaker-than-usual connections between the auditory cortex and the brain's reward centres, which are also involved in our enjoyment of food, sex and money. ***CJ***

EVERYONE AT WORK IS ILL. WHAT'S MY BEST COURSE OF ACTION TO AVOID GETTING THE PLAGUE FROM MY WORK COLLEAGUES?

If your colleagues are coughing and sneezing, your best hope is to ask them to go home. Failing that, get them to wear a tight-fitting 'N95' face mask (a 2018 study at the University of Hong Kong estimated that these block out 95 per cent of an infected person's germs). If you don't have one to hand, though, there are other things you can do. Move at least one metre away from your sickly colleagues to avoid any direct transmission from contaminated droplets sprayed by coughs and sneezes. Give them some antibacterial wipes to clean their desk surface (or do it yourself), and don't use their keyboard as this is a surface that's notorious for harbouring germs. Clear the air by opening a window or turning on the air conditioning (as long as it sucks in 100 per cent fresh air). And finally, look after yourself – stress makes you more susceptible because it weakens your immune system, so get plenty of sleep and eat well. ***HG***

AS SOON AS I GET COMFY IN BED, I NEED THE LOO. WHEN SHOULD I HAVE MY LAST DRINK BEFORE HITTING THE SACK?

It can take an hour or more for a glass of water to make its way down to your bladder, so you might want to cut out drinks an hour before bedtime. The strong urge you feel when you lie down is because your organs shift around and press on whatever is already in your bladder. Also, the worry that you might not be able to get to sleep until you've been to the loo tends to focus your attention and amplify the sensation. If you *do* need to get up for a pee, then rest assured that it'll probably be your last of the night – the sleeping body automatically downregulates the production of urine to keep you hydrated. ***LV***

JUSTIN GARDNER, LUTON

HOW DOES POPPING CANDY WORK?

FIZZ WIZ
SUPER LOUD
POPPING ACTION

Popping candy is made by heating the sugars sucrose, lactose and corn syrup (plus some flavouring) to boiling point. Carbon dioxide (CO_2) is bubbled through the molten mixture at a pressure of around 600 pounds per square inch (psi) – several times the pressure in a champagne bottle. The mixture is then cooled rapidly under pressure to prevent the gas from escaping as the candy solidifies. When the pressure is released, the candy shatters into smaller pieces, each containing tiny bubbles of CO_2 that remain trapped until the candy reaches your mouth. There, the warm, damp conditions dissolve the sugar, and the gas escapes with a satisfying pop. ***ED***

EDWARD SEYMOUR, HOVE

HOW DO SEIZURE ALERT DOGS PREDICT SEIZURES?

Seizure alert dogs are trained to give a consistent signal (such as barking, or jumping up and pawing), anywhere from 5 to 45 minutes before their owner suffers a seizure. The prevailing hypothesis is that the dogs are able to spot subtle behaviour cues, but it's also possible that they are detecting some unique smell – perhaps a chemical in their owner's sweat. Seizure alert dogs are a controversial topic of research and there is still some scepticism about how accurate their predictions are, never mind what the exact mechanism is. But seizure alert training is still valuable, because untrained dogs find it very stressful when their owner has a seizure, and training a dog to react in some predefined way before or during a seizure is reassuring to them. ***LV***

GETTY IMAGES X3, ALAMY X2 ILLUSTRATIONS: DAN BRIGHT

SARA STEVENSON, MAIDSTONE

IF YOUR ARMS WERE LONG ENOUGH, WOULD IT BE PHYSICALLY POSSIBLE TO SKIP WITH THEM?

No. And you can prove this for yourself with a simple experiment. Hold your hands behind your back and try lifting them above your head. You won't get very far because the shape of your shoulder joints means that each arm must tilt outwards from your body as it rotates back up over your head. Holding your arms close together stops this rotation from happening, and longer arms won't help with this.

A skipping rope gets around this problem by connecting your hands with a flexible line that is free to rotate through half a turn and then back again. The skipping rope is effectively extending the length of your fingers, rather than your arms, but even with very long fingers you would need to hold hands very loosely to allow them to rotate past each other. Some very flexible people can approximate a sort of arm skipping, but it's actually more of a rowing motion since each arm rises over their head alternately, to allow the arms to rotate one at a time. ***LV***

57,000

The approximate number of hermit crabs killed by getting stuck in plastic on the Cocos Islands and the Henderson Islands. Hermit crabs are attracted by the smell of their dead fellows, which made the problem worse.

HIDDEN FIGURES

ZHANG HENG

THE FIRST SEISMOLOGIST

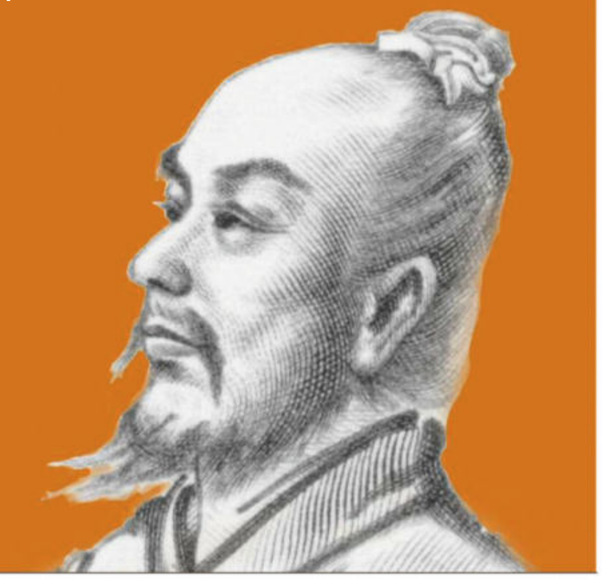
Earthquakes have killed countless people throughout history, but their cause was long based on little more than guesswork. Almost 2,000 years ago, a Chinese scholar took the first step towards the science of seismology by inventing an earthquake-detecting 'seismoscope'.

Born in the town of Xi'e in eastern China in 78 AD, Zhang Heng began his career as a civil servant. By his mid-30s, though, his brilliance had led him to join the court of the Emperor of China, and while there he became interested in the deadly phenomenon of earthquakes.

In 132 AD, Zhang built a device designed to detect and locate distant earthquakes. It took the form of a bronze urn with eight dragon heads equally spaced around its circumference. Inside, a delicate pendulum mechanism detected the ground movement caused by an earthquake's seismic waves, and triggered the release of a ball by one of the eight dragons, thus revealing the approximate direction of the quake.

In December 134 AD, Zhang's seismoscope detected a quake several hundred kilometres away that had not been felt by the court in Chang'an. Days later, the detection was confirmed by local sources.

While it couldn't measure the actual strength of an earthquake, Zhang's pioneering device is regarded as the precursor of modern seismometers – early versions of which still used pendulum mechanisms. *RM*



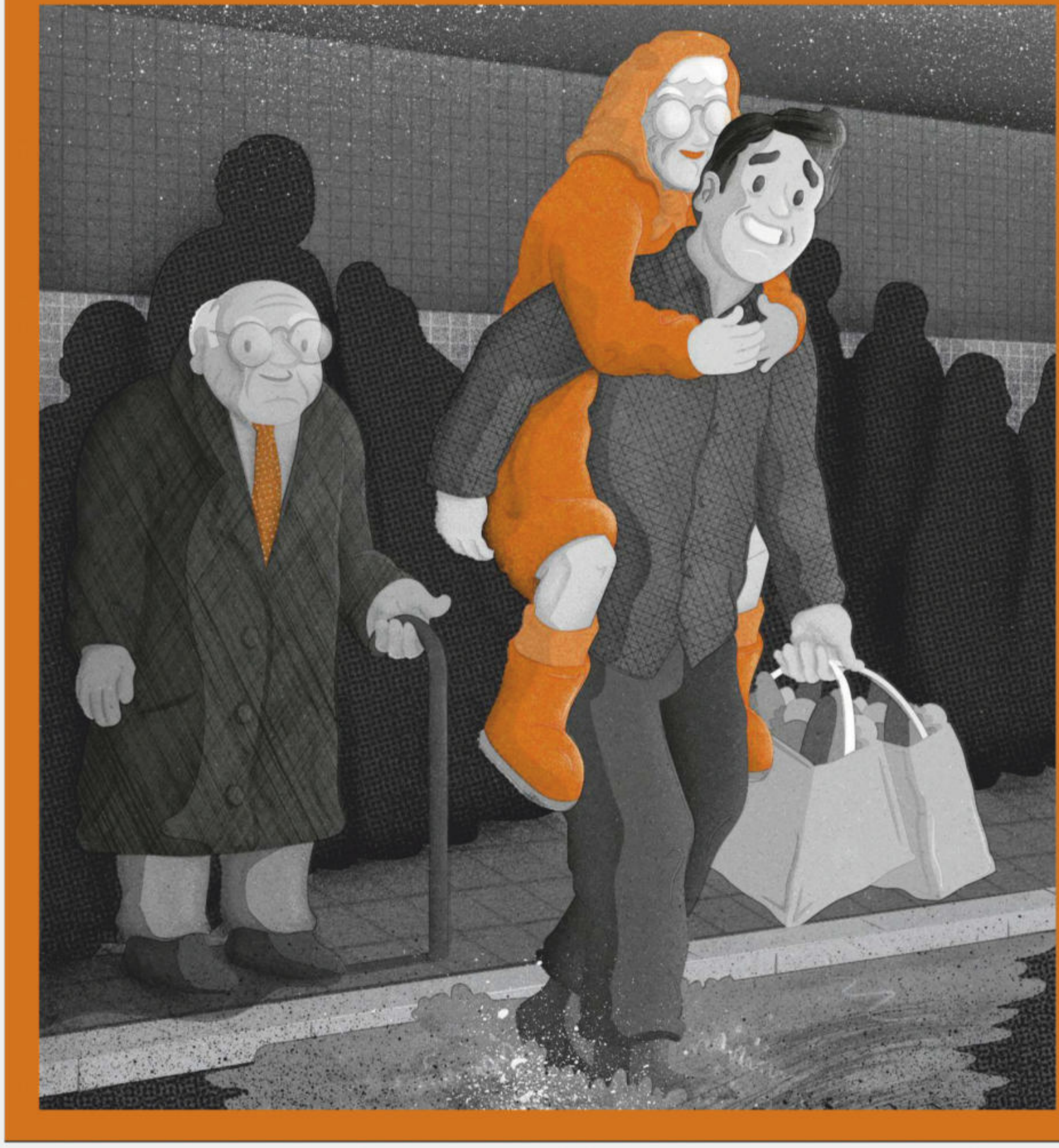
EXISTENTIAL FEAR OF THE MONTH...

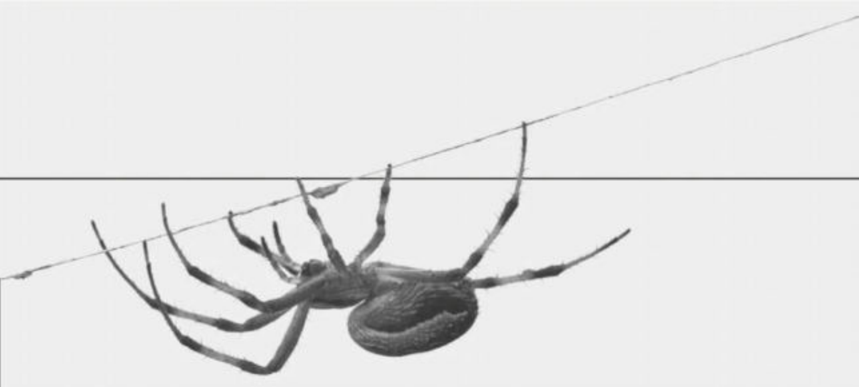
I'M TOO NICE, AND IT'S HOLDING ME BACK IN LIFE

In personality terms, psychologists would describe an extremely nice person like you as being a high scorer in the trait of 'agreeableness' – you're warm, trusting and friendly. Research shows that people like you tend to enjoy high-quality friendships and romantic relationships, and get into fewer arguments.

Unfortunately, though, just as you fear, being nice can be a disadvantage. For instance, research led by the University of Notre Dame in the US found that people rating higher in agreeableness tend to earn less – probably because nicer people are less competitive and are less likely to push for the more high-powered, higher-paid jobs. This correlation is particularly strong in men. Other research suggests that you could be losing out in the dating game, too. At least in the short-term, both men and women are especially sexually attracted to people who exhibit the 'dark triad' of personality traits, namely narcissism, psychopathy and Machiavellianism.

Obviously that's not the full story, though, and altruism is another trait that's appealing to potential partners – something that nice people have in spades. And while your friendly character might put you at an earning disadvantage, it might draw you to more meaningful work that you find rewarding. For example, a study at Bard College Berlin found that people who work for non-profit organisations are happier in their life and in their career than those in the profit-making sector. ***CJ***





REGAN COOK, VIA TWITTER

WHY DON'T SPIDERS GET CAUGHT IN THEIR OWN WEB?

Spiders only put glue droplets on some of their strands of silk, and they tend to avoid these as they move around their web. Spiders also only touch the web with the tips of their feet ('tarsi'), which have a non-stick coating. In addition, a special claw on the end of each foot grips the web and pulls it against springy hairs. When the claw is released, the springy hairs push the web strand away, stopping it from sticking. ***LV***

GLYN LEANEY, ASHFORD

WHERE DOES THE COLOUR GO WHEN A MATERIAL FADES IN THE SUN?

A material gets its colour from regions of its molecular structure known as 'chromophores', which absorb photons of visible light at particular wavelengths. Any photons that aren't absorbed are re-emitted, and the wavelength of these photons determines the colour that we see.

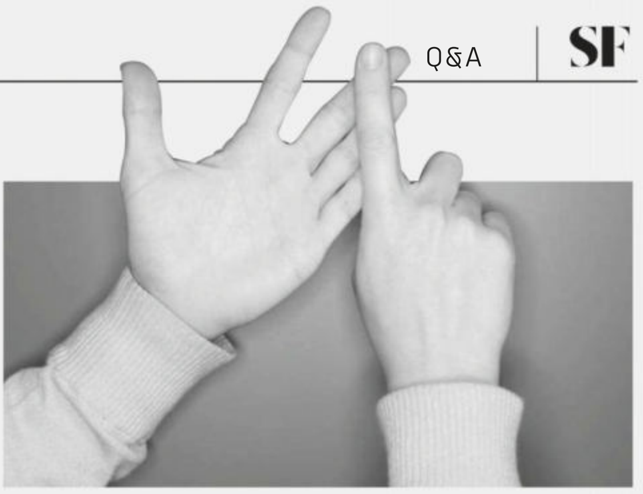
Over time, exposure to the higher-energy photons in sunlight can damage the structure of a material's chromophores, affecting their ability to emit photons at certain wavelengths. For example, red materials are particularly susceptible to fading in sunlight. The chromophores in these materials emit red light by mopping up photons of all the other wavelengths. Among these absorbed photons are those toward the blue – and higher-energy – end of the spectrum. Red materials are also good absorbers of photons of ultraviolet (UV) light, which have higher energies yet. The result is that the red-emitting chromophores degrade at a faster rate, triggering fading. So simply put, the colour doesn't 'go' anywhere when materials fade – it's just not emitted so well by the chromophores. ***RM***

GETTY IMAGES X4 ILLUSTRATIONS: DAN BRIGHT

RACHEL CAMPBELL, VIA EMAIL

WHAT DOES BIODEGRADABLE PLASTIC DEGRADE INTO?

Biodegradable plastics contain chemical additives that encourage microorganisms to feed on the plastic, using their enzymes to break the plastic's molecular bonds. These additives work in two main ways: either by attracting microbes to the plastic directly, or by speeding up the plastic's natural weathering process, which gives a larger, more ragged surface area for the microbes to work on. Once the microbes have done their work, all that's left behind is water, carbon dioxide, and methane. The reality is, however, a little more complex, as many biodegradable plastics need particular conditions in order to biodegrade. This typically involves temperatures of over 50°C and the right combination of moisture, air and microbes – meaning that these plastics won't break down if left in the ocean or on domestic compost heaps. Meanwhile, some plastics labelled as biodegradable aren't truly biodegradable but are merely designed to disintegrate into fragments when exposed to air. These plastics never decompose entirely, but leave behind tiny pieces known as microplastics. ***AFC***



HEIDI NELSON, LONDON

DO DEAF PEOPLE DO SIGN LANGUAGE IN THEIR SLEEP?

Anecdotally, some people who've learned sign language do occasionally use it in their sleep. There's not a lot of scientific data, but one 2017 case study describes a 71-year-old man with a severe hearing impairment, who also had 'rapid eye movement (REM) sleep behaviour disorder'. This involves a loss of paralysis during REM sleep, and the man was observed signing fluently. The researchers could even get an idea of what he was dreaming about by decoding his signs. ***AGr***

QUESTION OF THE MONTH

CERIAN BOLTON, ELY

WHAT IS THE EVOLUTIONARY BENEFIT OF MORNING SICKNESS DURING PREGNANCY?

Morning sickness in pregnancy appears to be unique to humans, and it seems that women with more severe morning sickness have a lower rate of miscarriage. There are two main theories to explain why we might have evolved this. The first is that the nausea is commonly associated with an aversion to meat and strong tastes, and this might be a way of steering the mother away from foods that might cause food poisoning, especially early in pregnancy when the foetus is most vulnerable. The second theory is that morning sickness is caused by the hormones secreted by healthy foetuses, which are important for building the placenta in the first trimester. In that case, the nausea is just an unfortunate side effect of these hormones, and the advantage is an indirect one. ***LV***

WINNER

Cerian wins a Somfy Indoor Security Camera, worth £139. This Full HD camera, with a two-way mic, is quick and easy to set up. It records everything and alerts you of any suspicious movement via a smartphone notification. With selective detection, you can exclude certain areas that you don't want to protect, and concentrate on the places that matter, like doors, windows and valuables. **shop.somfy.co.uk**

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM** OR TWEET US **@SCIENCEFOCUSQA**

RADAR

WHAT'S LIGHTING UP OUR ANTENNA THIS MONTH

The truth about fat
We talk obesity, health and diets with The Angry Chef Anthony Warner p92

Eat your greens
Gone vegan this month? Or thinking about it? Tune in to *Veganville* p94

Reading list
Curl up with our choice of the latest (and best) science books p94

Books that made me
Comedian and presenter Robin Ince reveals his favourite books p95

1

CHRIS PACKHAM: 7.7 BILLION PEOPLE & COUNTING

BBC Two

Environmentalist Chris Packham finds out whether Earth can meet the demands of 10 billion people, predicted by the UN to be the world's population by the year 2050.

In the March 2019 issue of *BBC Science Focus*, Chris told us that his "greatest worry of all is human population growth". In this documentary, he visits Nigeria, the country on track to become the third most populous nation in the next 30 years, and chats to Sir David Attenborough about the charity Population Matters.

January, check *Radio Times*

2

RSPB BIG GARDEN BIRDWATCH

Take an hour to note the birds in your garden and help the RSPB gauge the state of Britain's wildlife.

rspb.org.uk/birdwatch

25-27 January

3

RICHARD HAMMOND'S BIG!

Discovery Channel

An epic engineering exploration series sees Richard Hammond encounter some of the world's biggest structures, including a cargo ship the size of four football pitches and the longest underground railway tunnel. He finds out how they're made by meeting the minds behind them.

Starts 15 January, 9pm

4

YORKSHIRE GAMES FESTIVAL

Science and Media Museum, Bradford

This five-day festival is aimed at those in the gaming industry, but between 8-9 February it morphs into the *Let's Play!* family weekend. Gamers of all ages can get hands-on with activities, try brand-new games by local designers and attend live shows.

5-9 February

scienceandmediamuseum.org.uk

FOR THE FAMILY

BBC, JAMES HORAN, HAMISH PEARCH, SEANA GAVIN, ANDY HAY/RSPB

5

STAR TREK: PICARD

Sir Patrick Stewart returns as Jean-Luc Picard in this new 10-part series. It's an Amazon Prime exclusive, with episodes released every Friday.

From 24 January

amazon.co.uk/prime

6

TYRANNOSAURS

National Museum of Scotland, Edinburgh

See rare fossils, cast skeletons and incredible models in the *Tyrannosaurs* exhibit. You'll see the *T.rex* skeleton known as 'Scotty', but you'll also find out about other species in the *Tyrannosaurus* genus and the dinosaur's 100-million-year history.

From 23 January

nms.ac.uk/tyrannosaurs

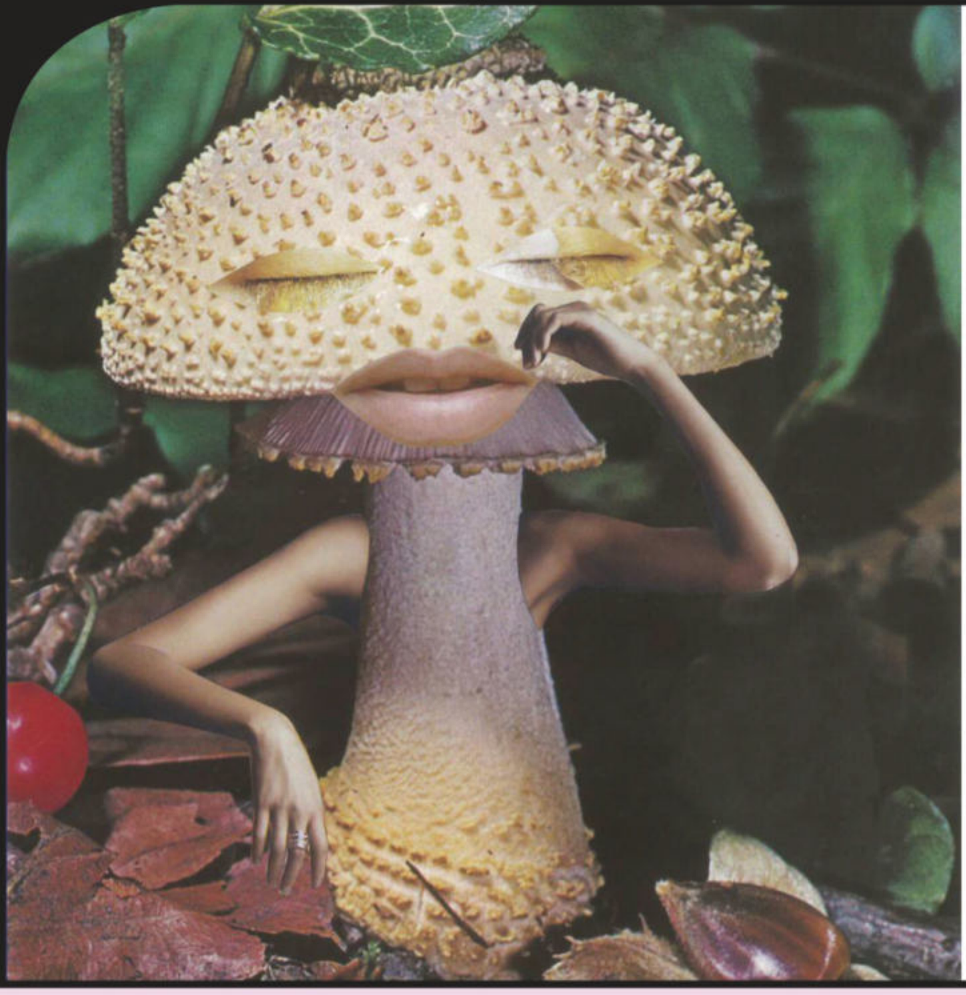
7

FIDGET ON FOUR

BBC Sounds

Are you clicking your pen right now? Jiggling your knee? You're not alone – most of us fidget, and so does Dr Kat Arney. In this 30-minute programme from BBC Radio 4, Kat finds out why we fidget, the therapeutic benefits of fidgeting, and how it might be converted into a tool for concentration.

Available now



8

MUSHROOMS: THE ART, DESIGN AND FUTURE OF FUNGI

Somerset House, London

Including work from artists, architects, scientists and more, *Mushrooms* is a fascinating look at the legacy and the potential of the fungal world. See the 'Mycelium Chair' by designer Tom Dixon, which depicts the strength of the branching tubes, known as hyphae, that form the structure of a fungus, and the 'Edible Utopia' food-growing project that uses waste coffee grounds from Somerset House's restaurants to grow mushrooms.

From 31 January

somersethouse.org.uk

Profile

FAT AND FICTION

ANTHONY WARNER, AKA THE ANGRY CHEF, REVEALS *THE TRUTH ABOUT FAT* IN HIS LATEST BOOK. HE TELLS US WHY OBESITY ISN'T AS SIMPLE AS IT SEEMS

WHAT IS THE TRUTH ABOUT FAT?

There are so many false beliefs and misinterpretations of scientific evidence in the world of food. It started to frustrate me, so I started a blog called *The Angry Chef* a few years ago about misinformation, lies, assumptions and pretensions in the world of food.

One of the most prevalent sources of misinformation is around fad and detox diets. You know, the sort of 'this food is medicine' narrative, which is very popular these days. Another is the obesity epidemic, which is obviously a massive part of public consciousness. It's incredibly prevalent when anyone's talking about food, but there's also an enormous amount that we get wrong.

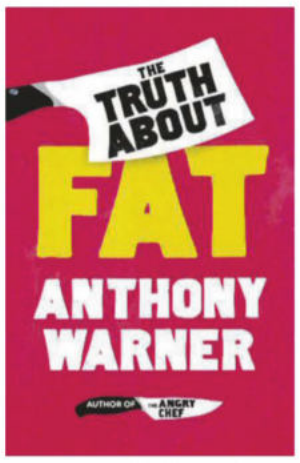
As I started to look into it, I realised that even I was getting stuff wrong. Not really understanding the science, falling back on folk beliefs and things that just felt right, which didn't match with what leading scientists were telling us. So much is written about the obesity epidemic and the problems that it causes, but so much of it is being used to sell us stuff, to make us feel guilty and to sell political visions as well.

> "I think for many people, this obsession with BMI as the sole marker of health is actually not that helpful"

I suppose the real drive behind writing *The Truth About Fat* is that when we get this stuff wrong, it's not benign. It's extremely harmful for large numbers of people. It causes a lot of hurt, a lot of illness and a lot of distress. I think that's something we're not talking about enough.

AS A POPULATION, HOW FAT ARE WE?

It depends what you mean. You see this data that says one in three people, roughly, is considered obese in the UK, which seems extraordinary. But then you have to strip that back and ask, "What does that actually mean?" and "What is obesity?"



THE TRUTH ABOUT FAT
ANTHONY WARNER
£9.99, ONEWORLD

Obesity is when someone has a body mass index (BMI) of over 30 and being overweight is when people have a BMI of over 25. This is rather than looking at an individual and saying, "Do they have a lot of excess weight? A lot of excess fat?" Plenty of people can have BMI of 30 or 25 or whatever and be perfectly healthy. There's no denying that there are correlations between having a high BMI and certain medical conditions, things like type 2 diabetes, heart disease or certain types of cancer. But correlation is not always causation.

Actually, there's plenty of evidence that our societal attitudes to people with higher weight actually cause a lot of the problems. Because people are living in what is essentially a marginalised body, they're subject to an enormous amount of stress and have lower life chances. So, that might end up causing a lot of the problems associated with obesity, such as cardiovascular disease.

I think we have to be very careful in interpreting it. The reality is, for many people, this obsession with BMI as the sole marker of health is not actually that helpful. It can make people pursue some odd ways of losing weight – they can end up taking weight-loss drugs (amphetamines basically) or go on ridiculous, extreme diets or start starving themselves.

SO, FOR THE AVERAGE PERSON WHO IS OVERWEIGHT OR CLASSED AS OBESE, WHAT IS IT THAT STOPS THEM LOSING THAT WEIGHT?

In biological terms, there are a lot [of barriers to losing weight]. Your body wants to be a certain weight. It sort of thinks, 'here's a good amount of fat for me to have in storage to maximise my chances of survival, and I'm going to get that amount of fat and try to keep it.' That's kind of how it works, in very simplistic terms.

There is an enormous number of hormones and control mechanisms that keep you at the weight you are – mostly controlled by quite primal parts of the brain. As soon as that amount of fat starts to drop, whatever that amount might be, your body thinks, 'We're in a bit of trouble here. We're starving and we're going to put in mechanisms to make sure that we don't starve.'

So it makes you extremely hungry; it gives you this incredible desire for food over the short term. But it also makes you driven and food-focused over the long term.

GETTY IMAGES

It's not a matter of willpower. These things happen by hormonal controls out of your conscious brain. It starts to slow down your metabolic rate, it starts to shut down your immune system (a lot of people who've dieted will tell you they become susceptible to illness); it starts making you feel miserable and it can have a profound effect on brain function. These are just the physical things. Societal things are a whole other layer on top of that.

IT'S THE TIME OF YEAR FOR NEW YEAR'S RESOLUTIONS. WHAT DO YOU SAY TO PEOPLE WHO ARE THINKING OF GOING ON A DIET IN 2020?

It's not for me to tell people what they should and shouldn't do. If anyone wants to lose weight, that's fine. I would say to people who are doing that: analyse the reasons why you want to lose weight. If it's about improving your health, that's understandable. But all the evidence says you'd be far better ensuring you do some exercise, eat a varied and interesting diet, and not smoke and drink to excess. Lots of us could do with a better diet – most of us don't eat enough fruits or vegetables.

There might be aesthetic reasons why people want to lose weight and that's fine too. But I would also think about what the issue really is. Often, people look at losing weight as the solution to all their problems, rather than thinking about what those problems are and a broader way to address them. They put their lives on hold because they want to reach a certain weight and that's enormously problematic.

You should be looking at behaviours to improve your life, rather than behaviours to change your weight.

ANTHONY WARNER

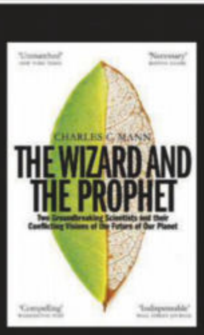
Anthony is an author and Sunday Times *columnist, and has worked as a professional chef for 25 years. Prior to that he was a scientist.*

Interviewed by* BBC Science Focus *editorial assistant Amy Barrett

DISCOVER MORE

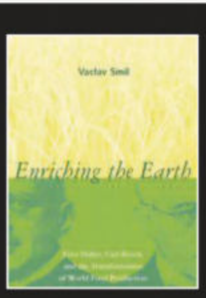
Subscribe to the Science Focus Podcast *and listen out for our full interview with Anthony in an upcoming episode.*
sciencefocus.com/science-focus-podcast

AUTHOR'S BOOKSHELF



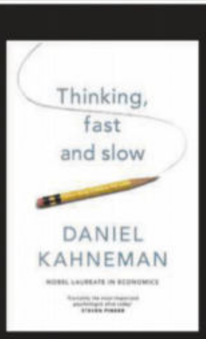
THE WIZARD AND THE PROPHET
CHARLES MANN
(£12.99, PICADOR)

This book is about food and science and progress, but also more about agriculture. It's along a similar line to the new book I'm writing, which is about sustainability.



ENRICHING THE EARTH
VACLAV SMIL
(£28, MIT PRESS)

Again, this book is about agriculture and how progress in food science saved billions of people from starvation, in a story that very few people know.



THINKING FAST AND SLOW
DANIEL KAHNEMAN
(£10, PENGUIN)

I'm interested in the psychology of eating and the reasons that we make certain food decisions. *Thinking Fast And Slow* was really influential in helping me understand why, psychologically, we get so many things wrong.

RECOMMENDED

WHAT'S CAUGHT OUR ATTENTION THIS MONTH

by **Amy Barrett**
EDITORIAL ASSISTANT

Now that you've supercharged your willpower (p54), it's time to think about your plans for the year ahead. If you're concerned about the carbon footprint of your diet, or just want a more animal-friendly lifestyle, January is a good month to try out a vegan diet. The ***Veganuary*** campaign was launched in the UK in 2014 and has a wealth of information, recipes and advice for those wanting to go vegan for a day, week, month or longer. I'm a meat-eater, but I'll be watching five vegans head to Wales and attempt to convert local omnivores in the new BBC Three series ***Veganville*** – perhaps they can convince me to try Veganuary, too? The three-part series is available on BBC iPlayer now.

The first ***The Sky At Night*** (BBC Four, 12 and 16 January) of 2020 will see Chris Lintott and the team shine a light on amateur astronomy. If you had a shiny telescope under the tree last month, or have resolved this year to pick up a new hobby, this programme will help you start looking to the stars.

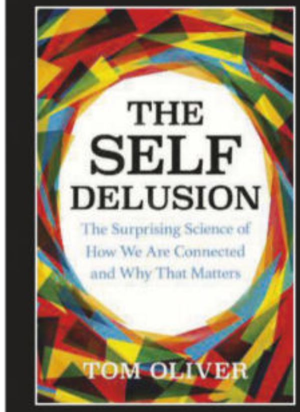
> "Five vegans head to Wales and attempt to convert local omnivores in the new BBC Three series *Veganville*"

VEGAN
DE EN ANIMA

This month sees two new exhibitions open in Newcastle, titled collectively as ***Illuminating The Self***. Here, artists respond to research from Newcastle University's CANDO project, where scientists are working to develop a brain implant that can prevent the development of seizures for some epilepsy patients. In a film by Andrew Carnie, the brain is represented by an Eden-like landscape, where trees are moved, changed and disrupted, just like neurons are by a seizure. In Susan Aldworth's response to the CANDO research, the testimonies of people living with epilepsy are sewn with ultra-violet threads onto white clothing, depicting the hidden nature of the disorder.

READING LIST

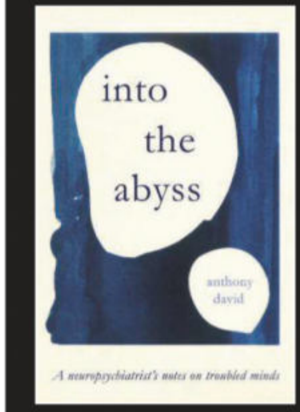
NEW BOOKS FOR YOUR BOOKSHELF


THE SELF DELUSION
The Surprising Science of How We Are Connected and Why That Matters
TOM OLIVER

THE SELF DELUSION

TOM OLIVER
£20, WEIDENFELD & NICOLSON

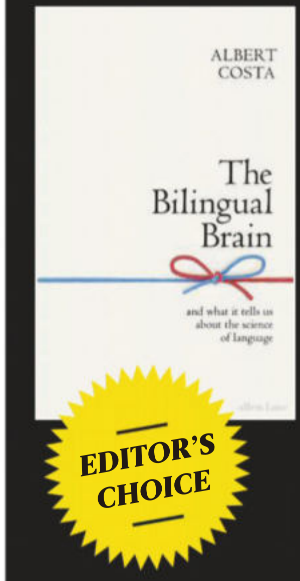
Ecologist Tom Oliver wants to dispel the myth that we are independent selves. We are not individuals acting autonomously in the world, he argues, but part of one connective reality and influencing one another in ways we don't even realise. For Oliver, understanding how we are all connected is the next step in human evolution.



INTO THE ABYSS

ANTHONY DAVID
£12.99, ONEWORLD

This collection of case studies documents neuropsychiatrist Anthony David's 40-year career. Each story is intertwined with the latest mental illness research. There is Caitlín, who seems immune to the feeling of hunger; Amy, whose life is so overwhelming she has intense seizures; Patrick, convinced he died in an accident. A deeply moving book.



THE BILINGUAL BRAIN

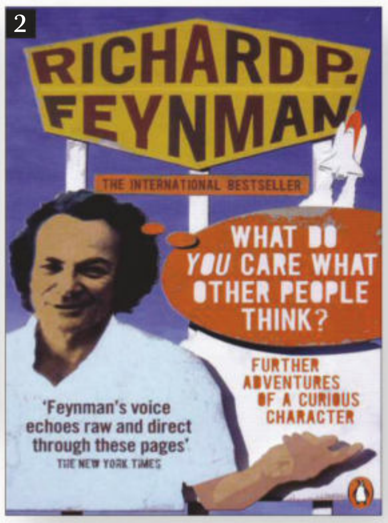
ALBERT COSTA
£20, ALLEN LANE

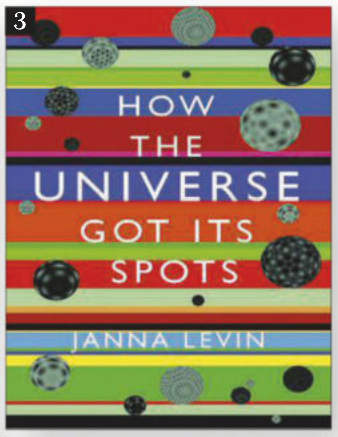
If you want to learn a language this year, you'll join the 40 per cent of Brits that speak two or more languages. But what do we really know about how the bilingual brain works? The late neuropsychologist Albert Costa spent two decades exploring this, and his book offers surprising insights from his research, such as a bilingual person is better at conflict resolution.

THE BOOKS THAT MADE ME: ROBIN INCE

FOR 10 YEARS, ROBIN INCE AND BRIAN COX HAVE PRESENTED THE BBC RADIO SHOW, *THE INFINITE MONKEY CAGE*. AHEAD OF THE NEW SERIES THIS JANUARY, COMEDIAN AND WRITER ROBIN INCE SHARES WITH US THE BOOKS THAT HAVE INFLUENCED HIM MOST.

1
Der Struwwelpeter
oder lustige Geschichten und drollige Bilder
Dr. Heinrich Hoffmann


2
RICHARD P. FEYNMAN
THE INTERNATIONAL BESTSELLER
WHAT DO YOU CARE WHAT OTHER PEOPLE THINK?
FURTHER ADVENTURES OF A CURIOUS CHARACTER
'Feynman's voice echoes raw and direct through these pages'
THE NEW YORK TIMES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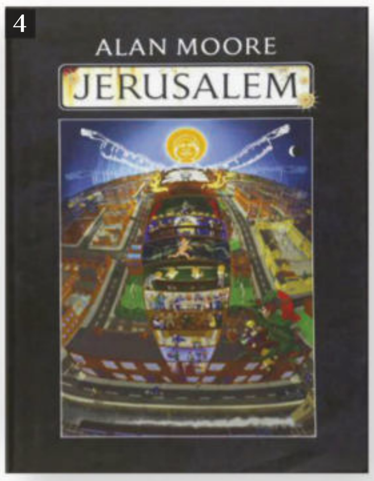

4

5
RE SEARCH
J.G. BALLARD

Whittling down the 'books that made me' to a mere six is a detestable challenge: there will have been six books that have remade me in the last month!

In childhood I was certainly influenced by the wonderfully barbaric warnings in the German children's book ***Der Struwwelpeter*** by Dr Heinrich Hoffman (1845). Though I still sucked my thumbs, knowing that the Long Legged Red Scissorman (one of the book's characters) was ready to cut them off played a part in their departure from my mouth.

I've chosen next ***What Do You Care What Other People Think?*** by Richard Feynman (1988). Like the more well-known *Surely You're Joking, Mr Feynman?*, this is a collection of transcriptions between Feynman and his partner in bongo-playing, Ralph Leighton. Two central stories in the collection – one about his involvement in the investigation into the Challenger Space Shuttle tragedy, and the other the story of the blossoming love and untimely death of his first wife, Arline – show Feynman as scientific in his observation of dying, yet also entirely human in his grief. His description of loss, and our reaction to it, is heartbreaking.

Janna Levin is a writer who, in ***How The Universe Got Its Spots*** (2002), changes the way you look up at the night sky and wonder about how this immensity exists. Her science is rigorous; intriguing and enlightening physics is woven into her personal story acclimatising to a new working environment and shoddy Brighton bedsits.

Alan Moore is ferociously original. He's a polymath whose fascination with science and magic, and the overlap between the two, gives him an ability to create something that is both familiar and utterly uncanny. He started with *Doctor Who Weekly*, continued with *V For Vendetta* and *Watchmen*, but I have chosen ***Jerusalem***, a novel based around ideas of the 'block universe'. It's also longer than the Old Testament.

Next, I have chosen ***Re/Search 8/9*** but I will buy anything by JG Ballard: one of the wisest men who ever lived and, if you read articles by his daughters, a rather wonderful parent too. His insight into human nature, and our reaction to technology, remains both prescient and disturbing, but also rather wonderful.

Rather than a sixth book, I am going to use all the word count I have left to list some of the other books that have made me, 'me' – Oliver Sacks's ***The Man Who Mistook His Wife For A Hat*** (such humanity), Jane Goodall's ***In The Shadow Of Man*** (such tenacity, such passion to learn and educate), ***Galapagos*** by Kurt Vonnegut (a novelist of both bleak and yet somehow optimistic philosophy), James Baldwin's ***Notes Of A Native Son*** (one the great poetic activists), Carl Sagan's ***The Demon-Haunted World*** (the book that reignited my love of science), Diane Ackerman's ***An Alchemy Of Mind*** (an author who writes with beauty that makes the subject utterly alluring)… and… and… and…

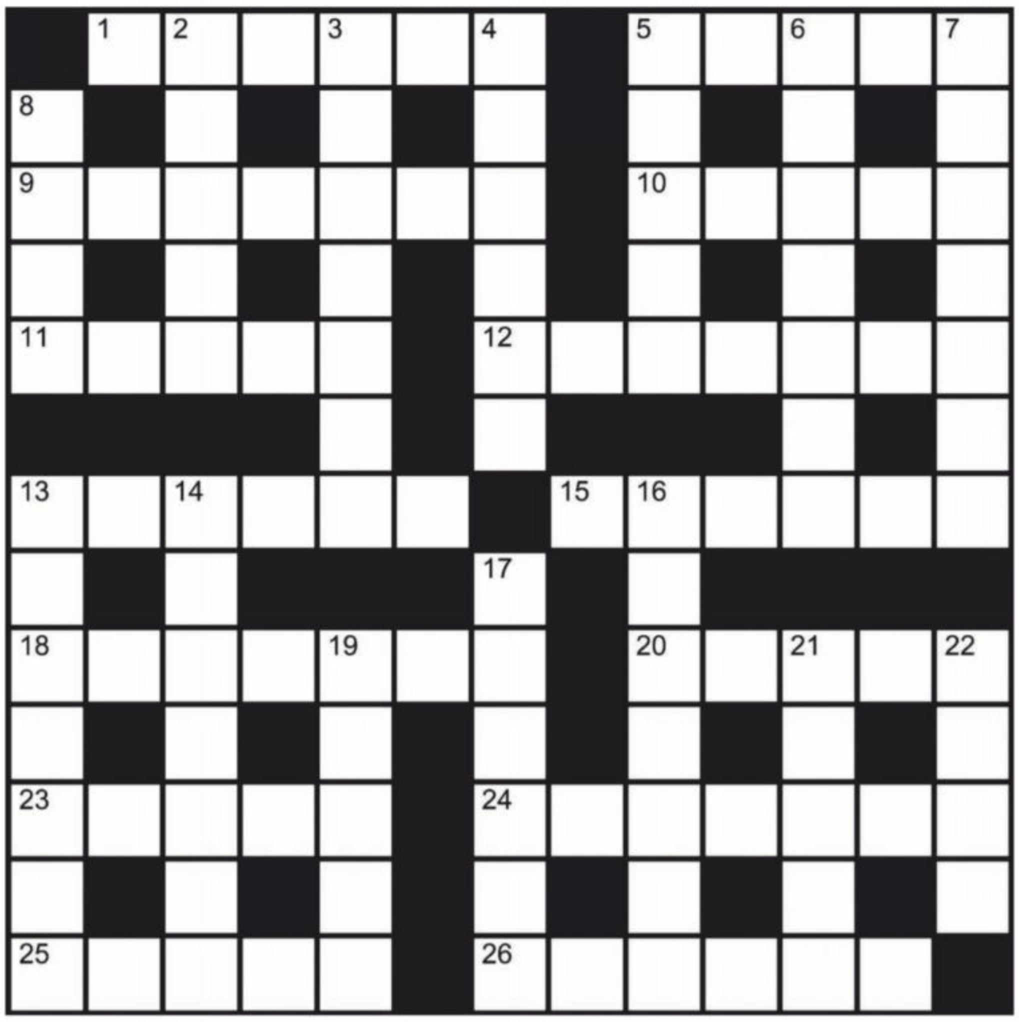
> "Intriguing and enlightening physics is woven into her personal story acclimatising to a new working environment and shoddy Brighton bedsits"

FRED WINDSOR/BBC

by **ROBIN INCE**
(@robinince)
Robin is a comedian, writer and presenter. He is co-presenter of The Infinite Monkey Cage, *which returns with a new series on BBC Radio 4 this month. Robin will also be hosting a new event about our blue planet, called* Sea Shambles, *at the Royal Albert Hall this May.*

CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

1 Abandon registered bear outside (6)
5 Slow progress on land, fast in water (5)
9 One rail moved to back of the wing (7)
10 Narcotic work one joins with hesitation (5)
11 No right to ditch fish (5)
12 Animal concealed in cane construction (7)
13 Way soldier returns to mother in disgrace (6)
15 In the morning, old English graduate finds tiny creature (6)
18 Silver necklace ultimately not so much lasting forever (7)
20 Mastermind rejects fourth category (5)
23 He guides you and me to that woman (5)
24 Engineers use pedal power to convert waste (7)
25 Depressed by queen being inferior (5)
26 A shade cowardly (6)

DOWN

2 Working a lot with new nail (5)
3 Sailor, artist, actor and patriarch (7)
4 City that provides parking warden with boot (6)
5 Idiot gets hard material (5)
6 Cretan princess provides song with different end (7)
7 Greek character has a dance (7)
8 Deer shows compassion but no energy (4)
13 Bird wasted ages on university students (7)
14 Diamonds reveal a form of entertainment (3,4)
16 Fantastic wise men caught by a lake (7)
17 A cat is off course (6)
19 Fear didn't start mistake (5)
21 Snack of sodium, carbon, hydrogen and oxygen (5)
22 Details of his pectorals (4)

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

GETTY IMAGES

NEXT ISSUE

COMET INTERCEPTORS

Meet the scientists who are hoping to capture a space rock that's come all the way from another galaxy.

PLUS

WHAT IF WE BANNED FISHING?

RECREATING SPACE ON PLANET EARTH

HOW TO ARGUE WITH A RACIST

With geneticist Dr Adam Rutherford.

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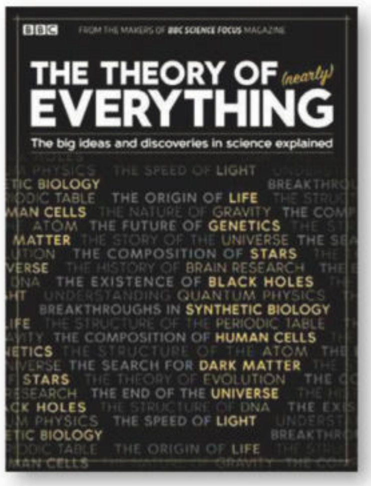
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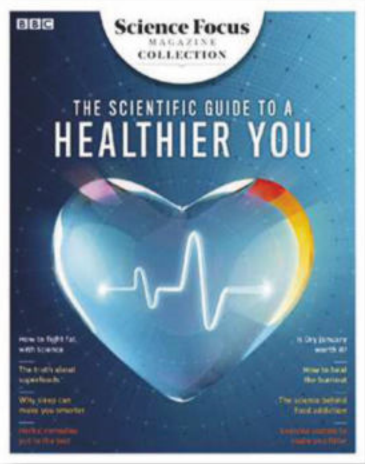
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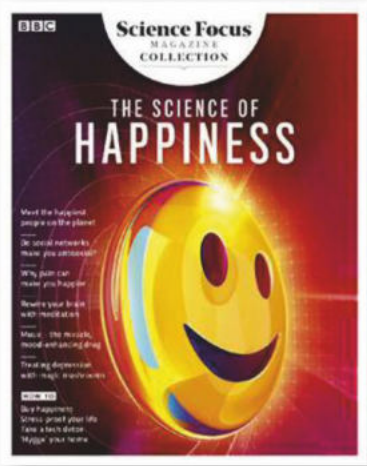
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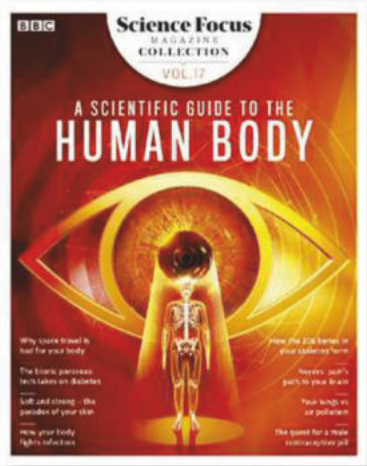
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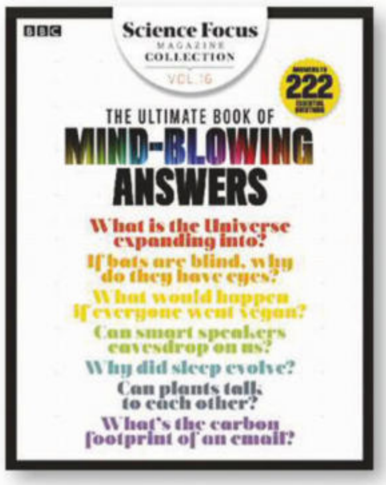
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THE ULTIMATE BOOK OF MIND-BLOWING ANSWERS
222
What is the Universe expanding into?
If bats are blind, why do they have eyes?
What would happen if everyone went vegan?
Can smart speakers eavesdrop on us?
Why did sleep evolve?
Can plants talk to each other?
What's the carbon footprint of an email?

Truth is often stranger than fiction, as the 222 mind-blowing answers to what seem like simple questions demonstrate in this Special Edition.

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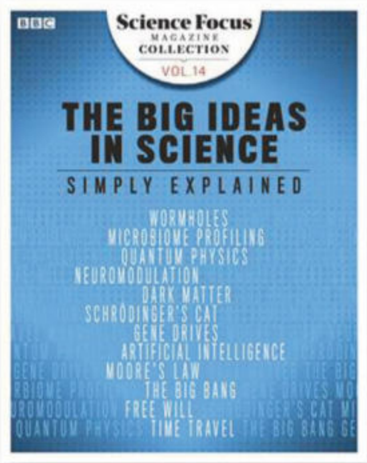
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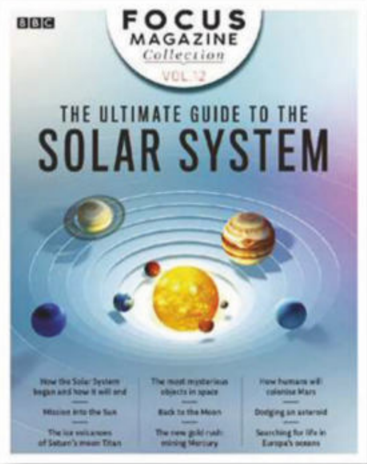
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A SCIENTIST'S GUIDE TO LIFE

HOW TO BEAT A COLD

AS THE NEW YEAR BEGINS AND THE DAYS GET CHILLIER, COMMON COLD EXPERT **RON ECCLES** REVEALS THE BEST WAYS TO TACKLE THE SNIFFLES

I'M FEELING DREADFUL. WHERE DO I BEGIN?

Our studies found that hot blackcurrant cordial is great at easing coughs and sore throats, but it can be any hot flavoured drink. Honey and lemon is good. The tastier the better as this helps to promote salivation and mucus secretion, which lubricates and soothes the throat.

SHOULD I ADD A LITTLE BRANDY TO MY HOT LEMON?

Alcohol in moderation is a sedative, so it can help you sleep and stop coughing. Don't overdo it though because alcohol dilates the blood vessels in the nose and can make it become more blocked.

MY MUM SWEARS BY HOT SOUP. COULD SHE BE ON TO SOMETHING?

Soup is hot and tasty so that works well, but our research shows that sweet tastes are good because they help inhibit coughs. Bitter-tasting things don't do that. Also, conventional shop-bought cold remedies can only be taken once every six hours or so, but you can have as much hot cordial or soup as you like.

WHAT ELSE SHOULD I TAKE?

An analgesic, like paracetamol or ibuprofen, for the sore throat, aches and chills, and a nasal decongestant spray, to relieve the stuffiness. The nasal spray is great because it works within minutes and the effects last for eight hours, so it can take you right through the night.

ISN'T IT EASIER TO BUY AN OVER-THE-COUNTER REMEDY THAT CONTAINS ALL THESE INGREDIENTS?

It might be easier, but it will be more expensive and it won't necessarily be better. The syrups and powders that you buy contain a different decongestant called phenylephrine, which is of questionable efficacy.

HOW ABOUT ALTERNATIVE THERAPIES?

There's some weak evidence that echinacea can help ease symptoms and shorten the duration of a cold. Similarly, there's mild evidence in favour of using garlic, and mixed evidence for the use of oral zinc supplements.

WHAT ABOUT VITAMIN C?

Vitamin C is good for you if you're deficient in it, but most of us have normal levels. Instead, I recommend a vitamin D supplement. Vitamin D is important for immune system functioning. We can get it from sunshine, but during the winter months, we get a lot less.

I STILL FEEL RUBBISH. WHAT ELSE CAN I DO?

Treat yourself to a trip to the cinema or an evening out. If you dwell on your symptoms, you'll only feel worse, but if you get out and distract yourself, your cold won't feel so bad.

WHAT ARE THE BEST PREVENTATIVE MEASURES?

Maintain a good, balanced diet with plenty of fresh fruit and vegetables. Exercise moderately, avoid stress, and make sure you get enough sleep. If all else fails, become a hermit and avoid all contact with human beings. If you do this you will never catch a cold! SF

DR RON ECCLES

Ron is emeritus professor at Cardiff University's School of Bioscience, and former director of the Common Cold Centre.

Interviewed by Dr Helen Pilcher.

NEED TO KNOW...

1

Enjoy lots of hot, tasty drinks and soups. They'll soothe your throat.

2

Painkillers and decongestant sprays are just as good as pricier all-in-one products.

3

Treat yourself to something fun to take your mind off your symptoms.

ILLUSTRATION: TOM REDFERN

LEAVE MANAGEMENT MADE EASY

- ☑ I manage staff leave
- ☑ Our staff work the same days or hours each week
- ☑ I may use a spreadsheet to manage my staff leave
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- ☑ Our staff have the same leave holiday year
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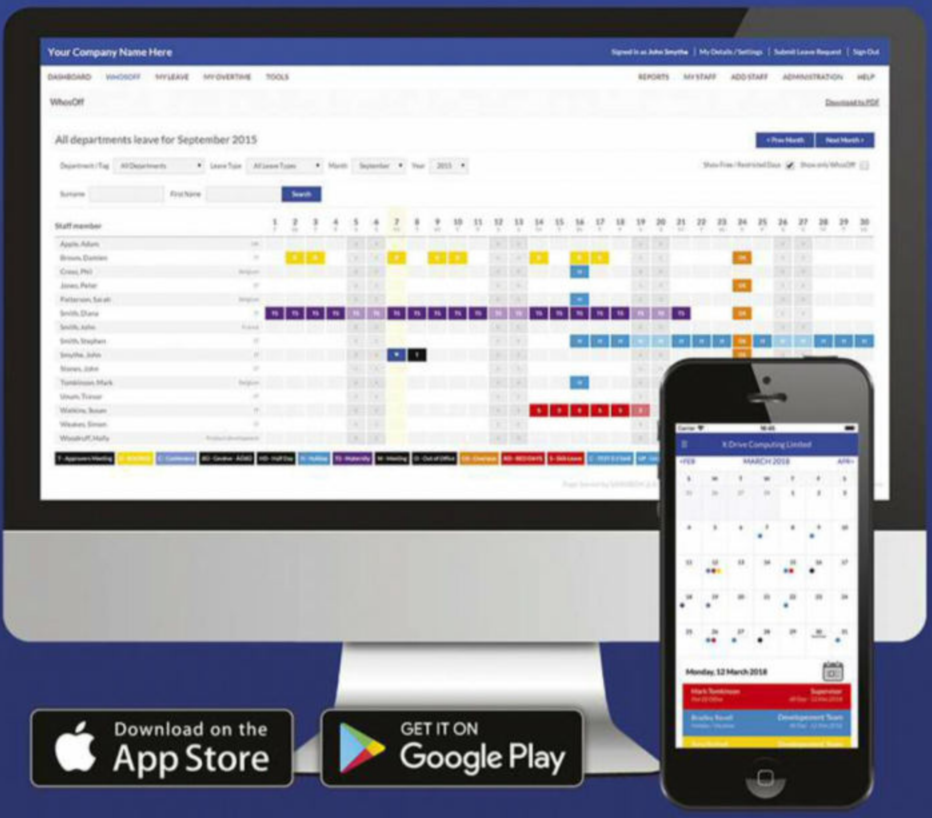
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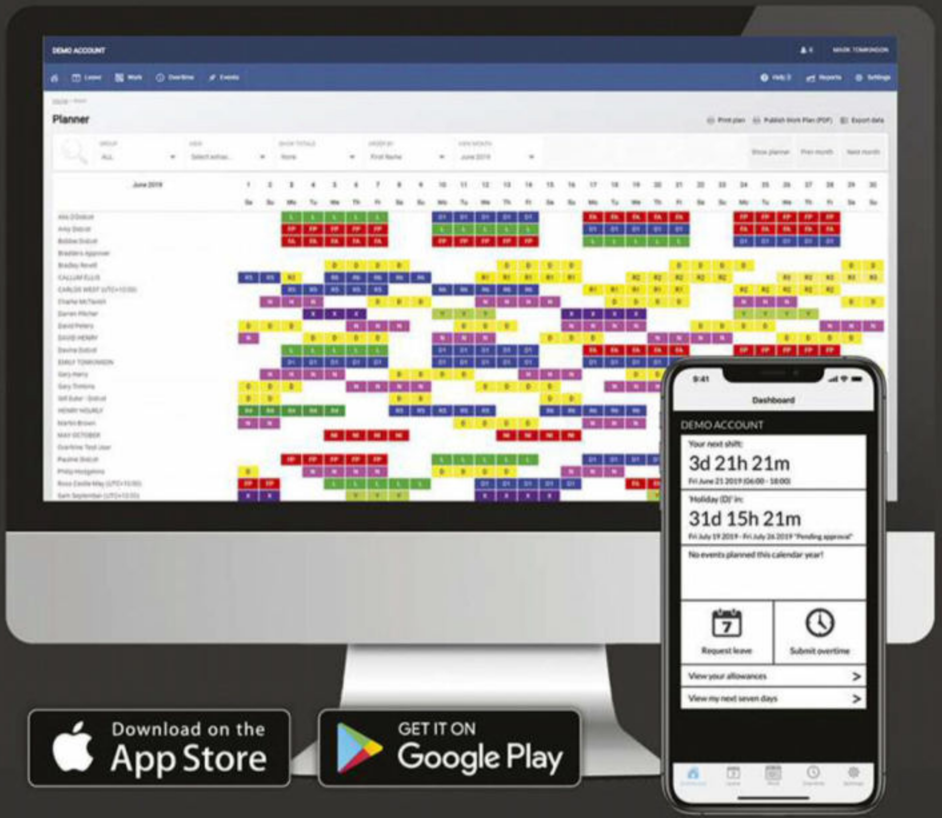
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